US009478099B2

(12) **United States Patent**
Czyzewski et al.

(10) **Patent No.: US 9,478,099 B2**
(45) **Date of Patent: Oct. 25, 2016**

(54) **BET SENSING APPARATUSES AND METHODS**

(71) Applicant: **Bally Gaming, Inc.**, Las Vegas, NV (US)

(72) Inventors: **Zbigniew Czyzewski**, Henderson, NV (US); **Nathan J. Wadds**, Las Vegas, NV (US); **David Bajorins**, Bothell, WA (US); **Daniel Fox**, Duvall, WA (US); **Maciej A. Jakuc**, Everett, WA (US)

(73) Assignee: **Bally Gaming, Inc.**, Las Vegas, NV (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 85 days.

(21) Appl. No.: **14/500,687**

(22) Filed: **Sep. 29, 2014**

(65) **Prior Publication Data**

US 2015/0018083 A1 Jan. 15, 2015

Related U.S. Application Data

(63) Continuation-in-part of application No. 13/829,843, filed on Mar. 14, 2013, now Pat. No. 8,961,298.

(60) Provisional application No. 61/751,780, filed on Jan. 11, 2013.

(51) **Int. Cl.**

A63F 9/24	(2006.01)
A63F 13/00	(2014.01)
G06F 17/00	(2006.01)

(Continued)

(52) **U.S. Cl.**

CPC ***G07F 17/322*** (2013.01); ***G07F 17/3204*** (2013.01); *G07F 17/3288* (2013.01)

(58) **Field of Classification Search**

CPC G07F 17/322; G07F 17/3204; G07F 17/3288; G07F 17/3248

See application file for complete search history.

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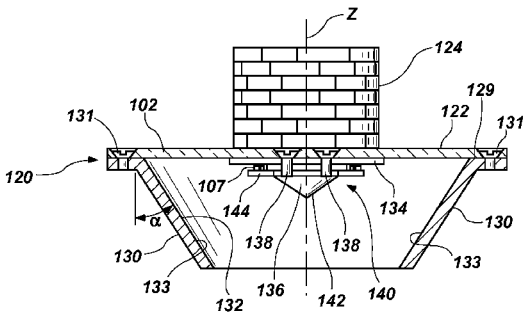
Primary Examiner — Kevin Y Kim

(74) *Attorney, Agent, or Firm* — TraskBritt

(57) **ABSTRACT**

A bet sensor for sensing values of gaming tokens may include a bet placement surface configured and oriented to support a stack of gaming tokens thereon and an image sensor located and oriented to capture an image of a lateral side surface of at least one gaming token located on the bet placement surface. The image may depict the lateral side surface in a radial format. The bet sensor may include a processor in communication with the image sensor. The processor is configured to acquire image data from the image and analyze the image data to determine a wager value of the at least one token. A gaming table may include such a bet sensor. The disclosure includes methods of operating such a gaming table.

42 Claims, 22 Drawing Sheets



(51) **Int. Cl.**

G06F 19/00	(2011.01)
G07F 17/32	(2006.01)

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2003/0087694	A1	5/2003	Storch
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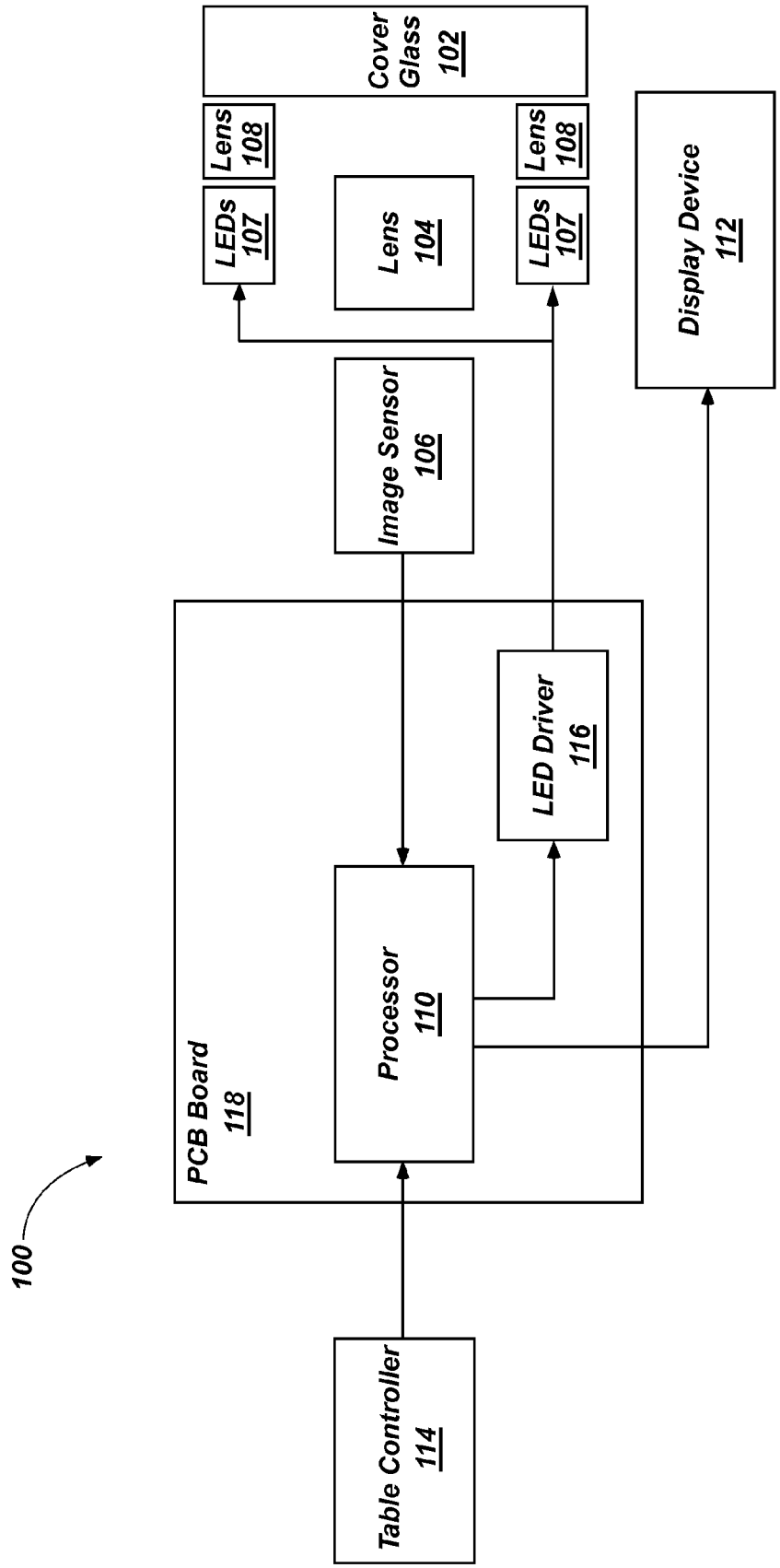

Cover Glass 102
Lens 108
LEDs 107
Lens 104
Lens 108
LEDs 107
Display Device 112
Image Sensor 106
PCB Board 118
LED Driver 116
Processor 110
Table Controller 114
100

FIG. 1

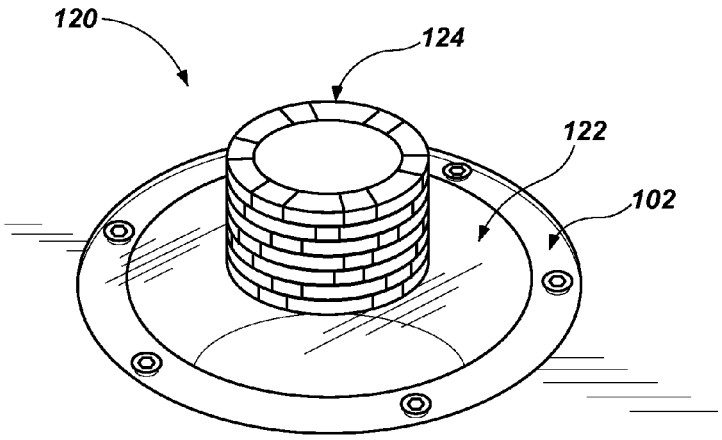


FIG. 2

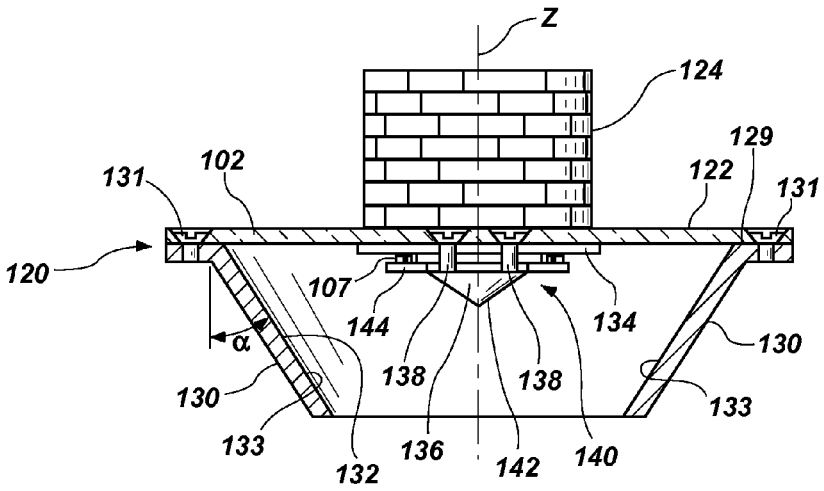


FIG. 3

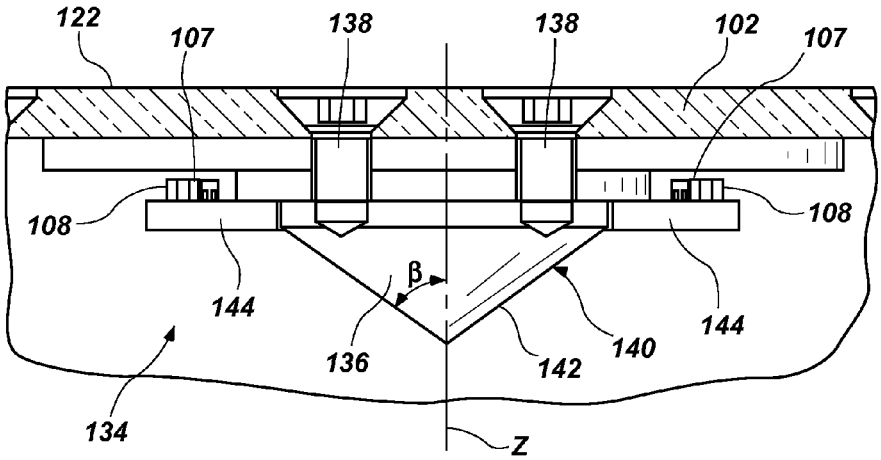


FIG. 4

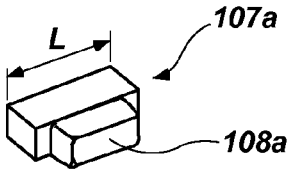
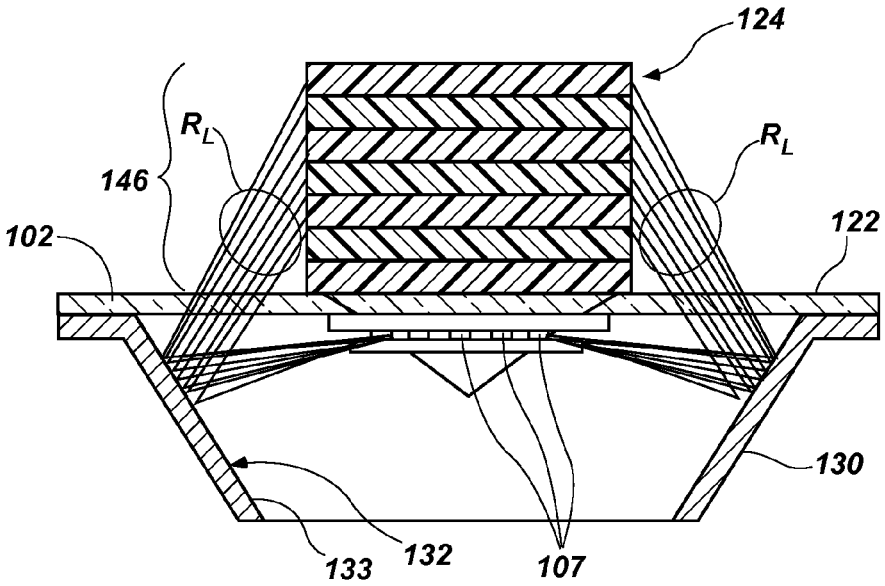


FIG. 5



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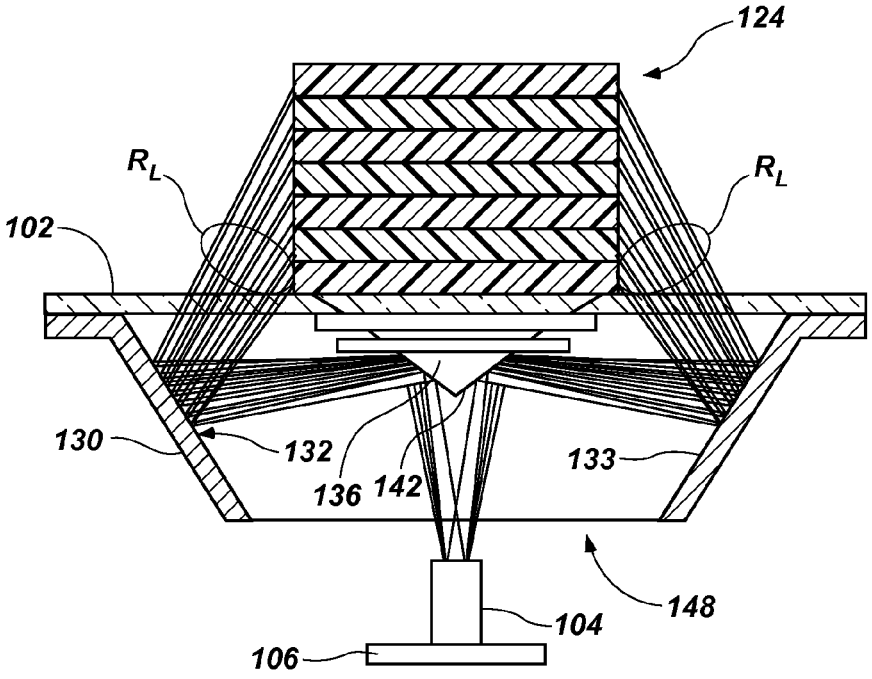

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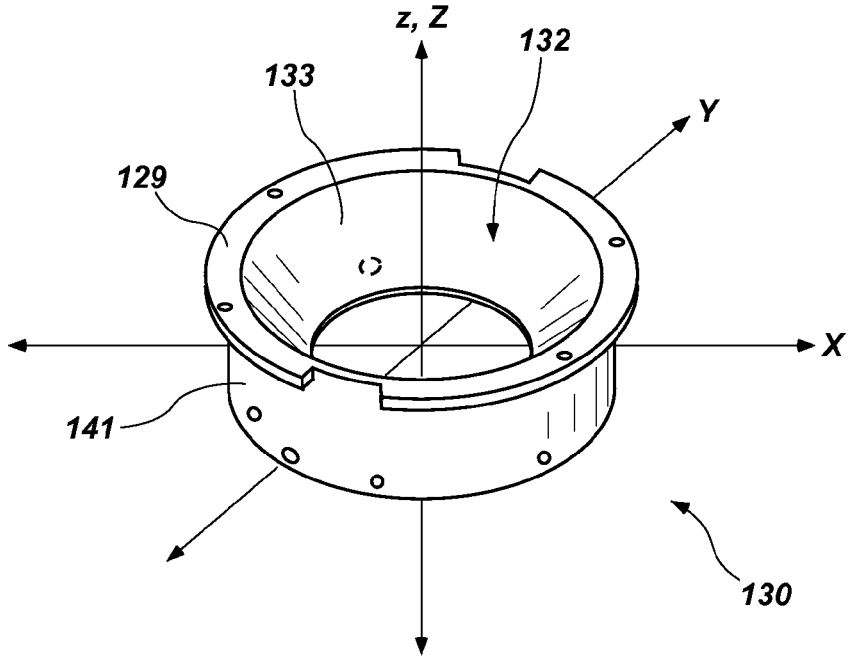
z, Z
132
133
Y
129
X
141
130

FIG. 8

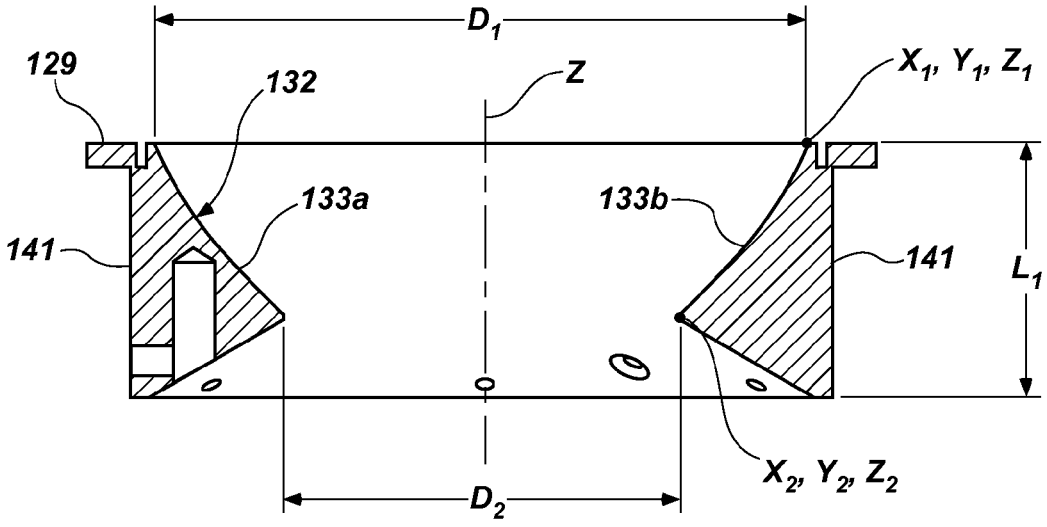
D_1
129
132
Z
X_1, Y_1, Z_1
133a
133b
141
141
L_1
X_2, Y_2, Z_2
D_2

FIG. 9

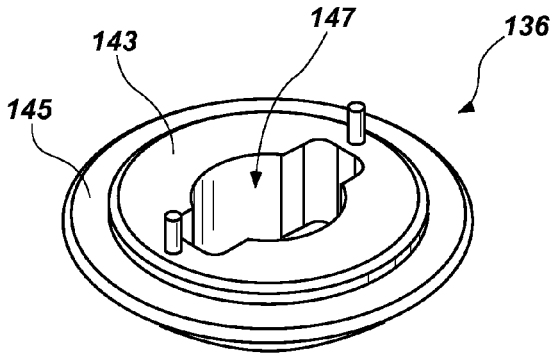

FIG. 10

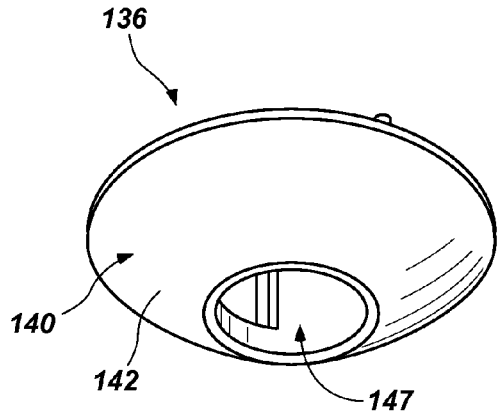

FIG. 11

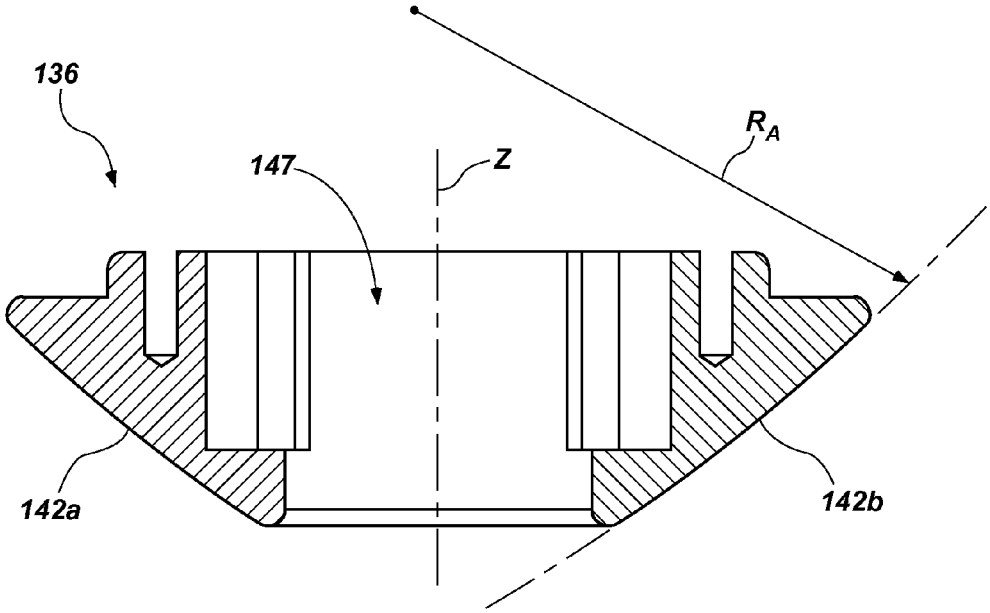

FIG. 12

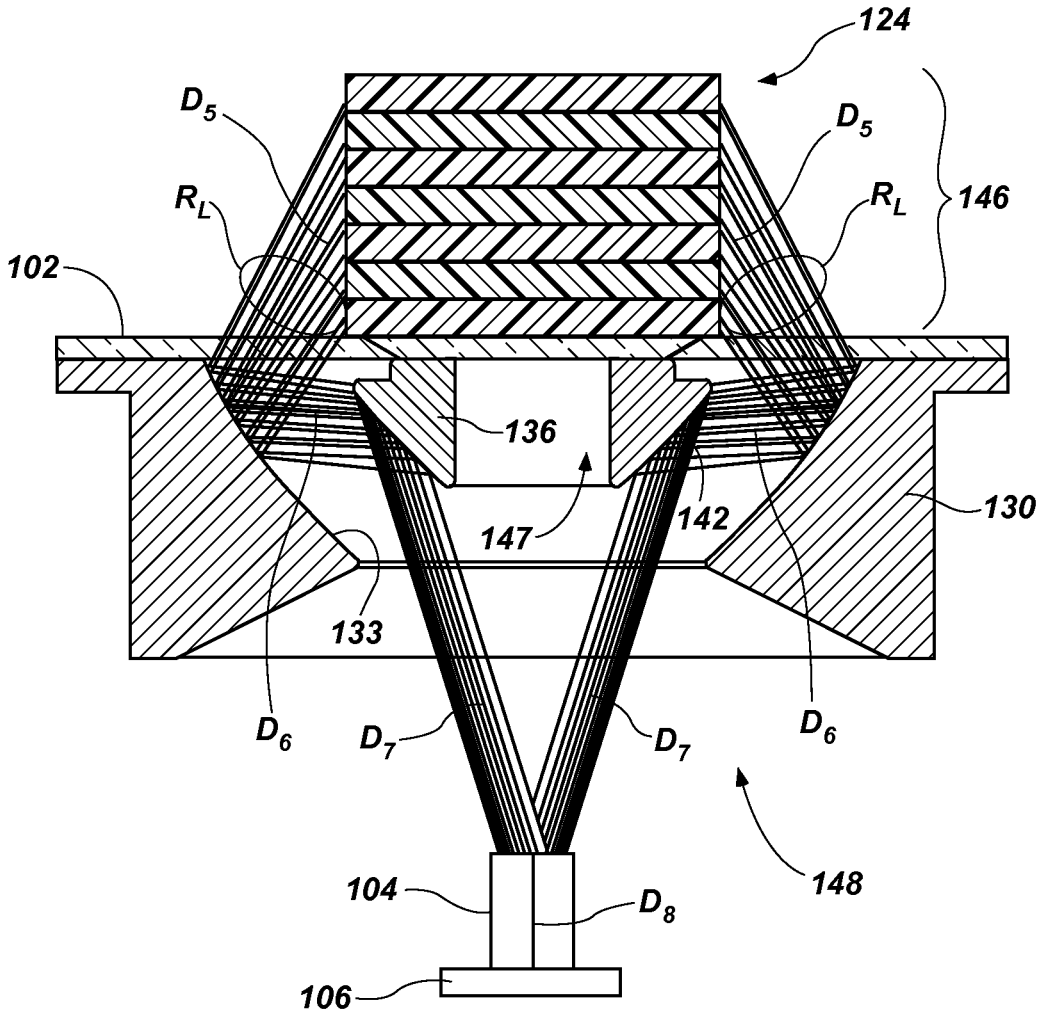
124
D_5
D_5
R_L
R_L
146
102
136
147
142
130
133
D_6
D_7
D_7
D_6
148
104
D_8
106

FIG. 13

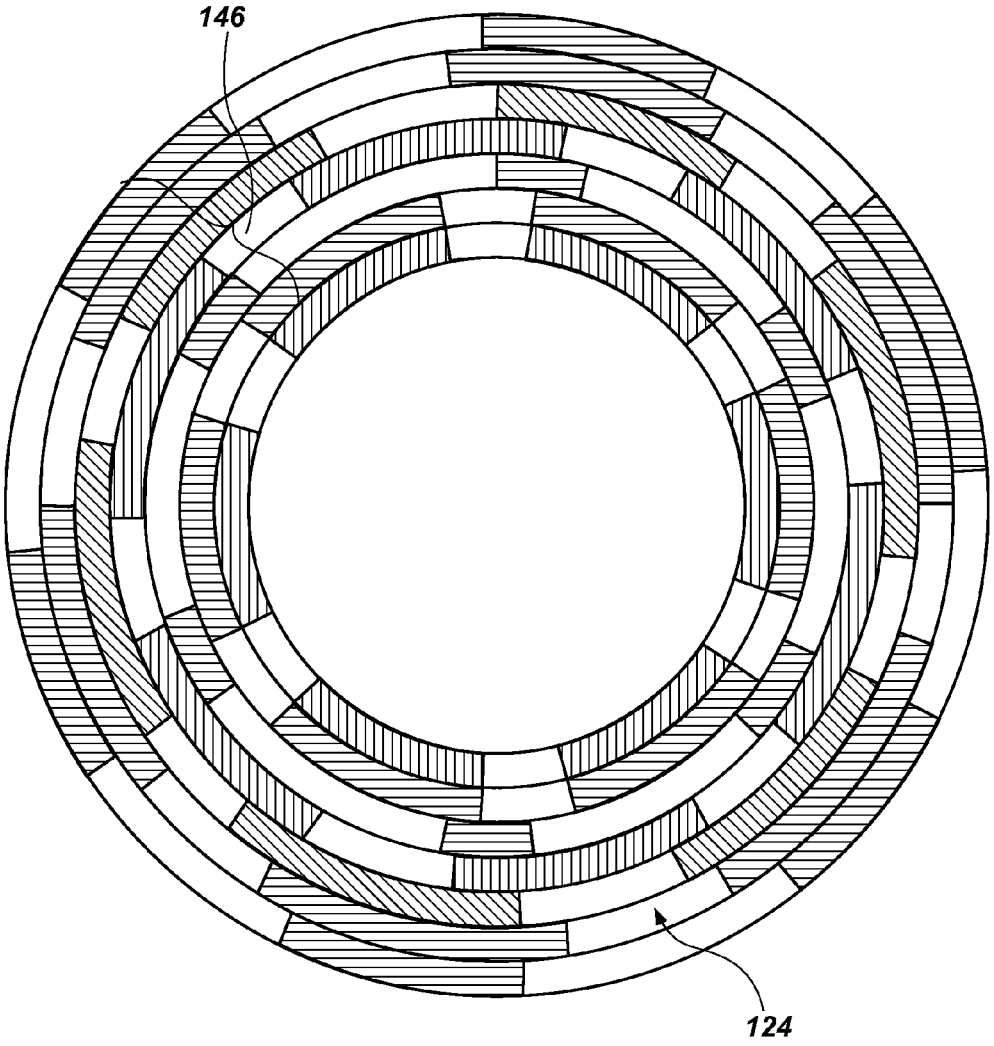

FIG. 14A

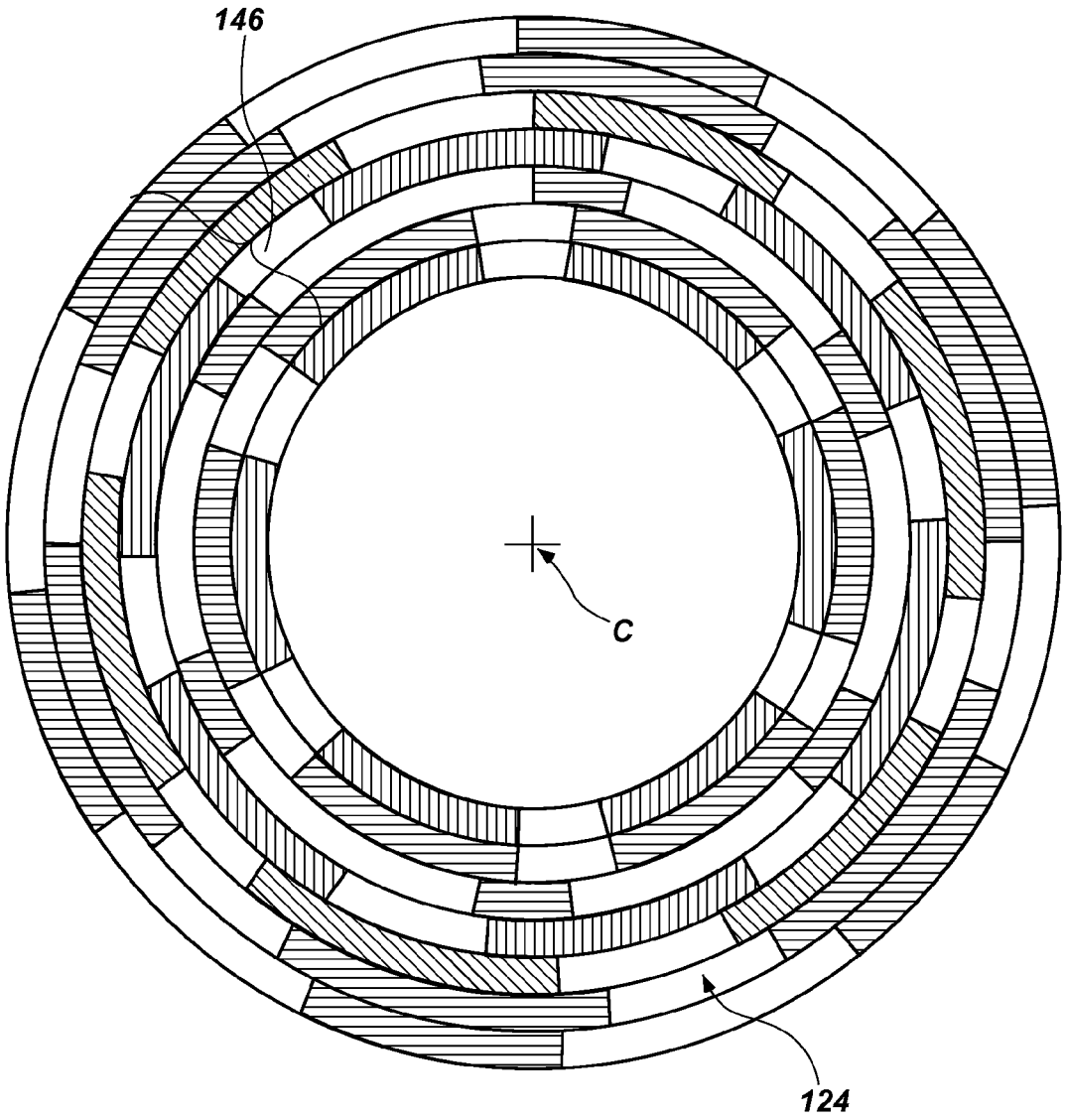

FIG. 14B

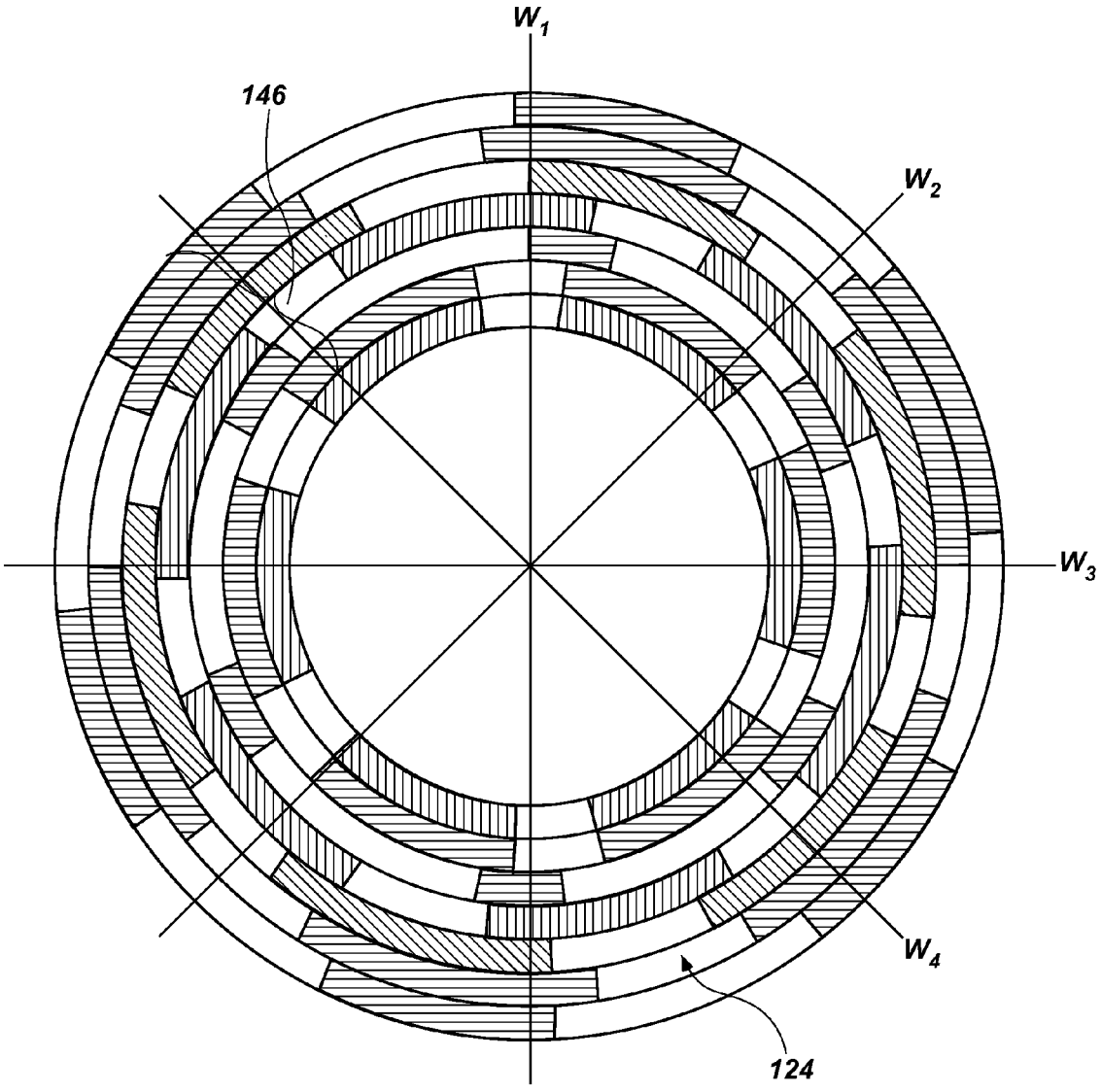

FIG. 14C

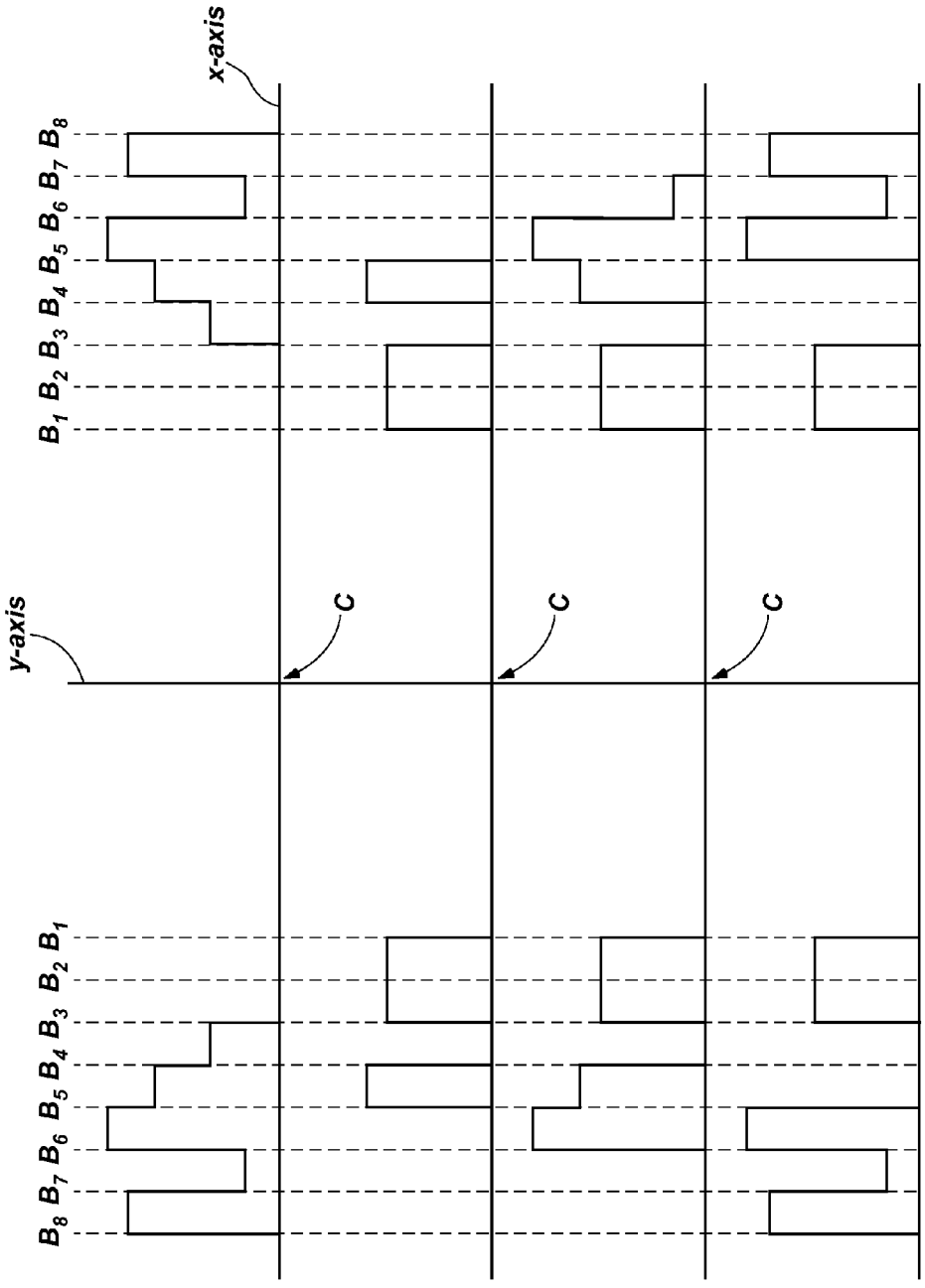

FIG. 14D

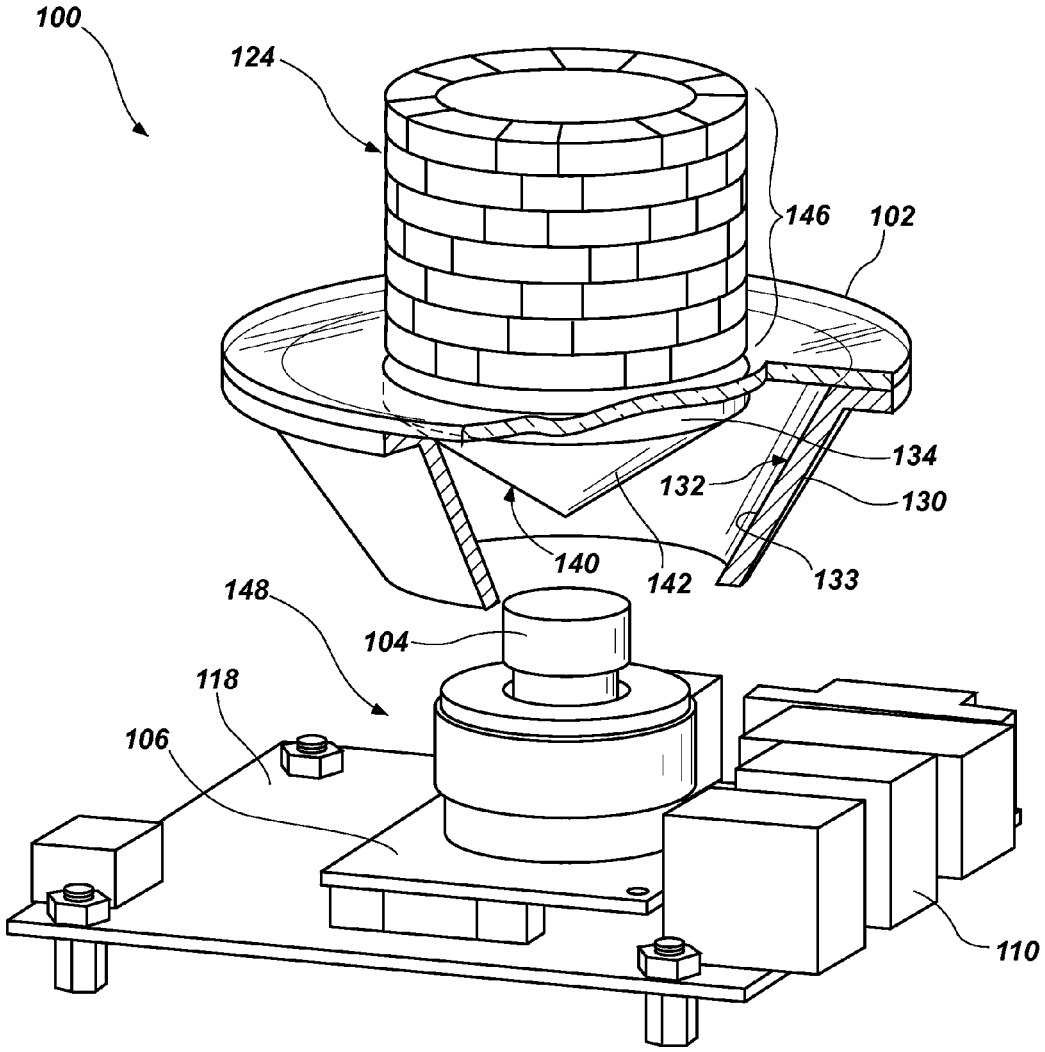
100
124
146
102
134
132
130
140
142
133
148
104
118
106
110

FIG. 15

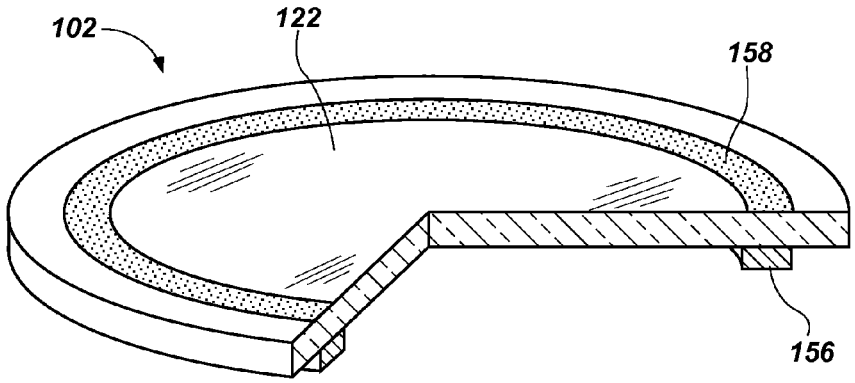
102
122
158
156

FIG. 16

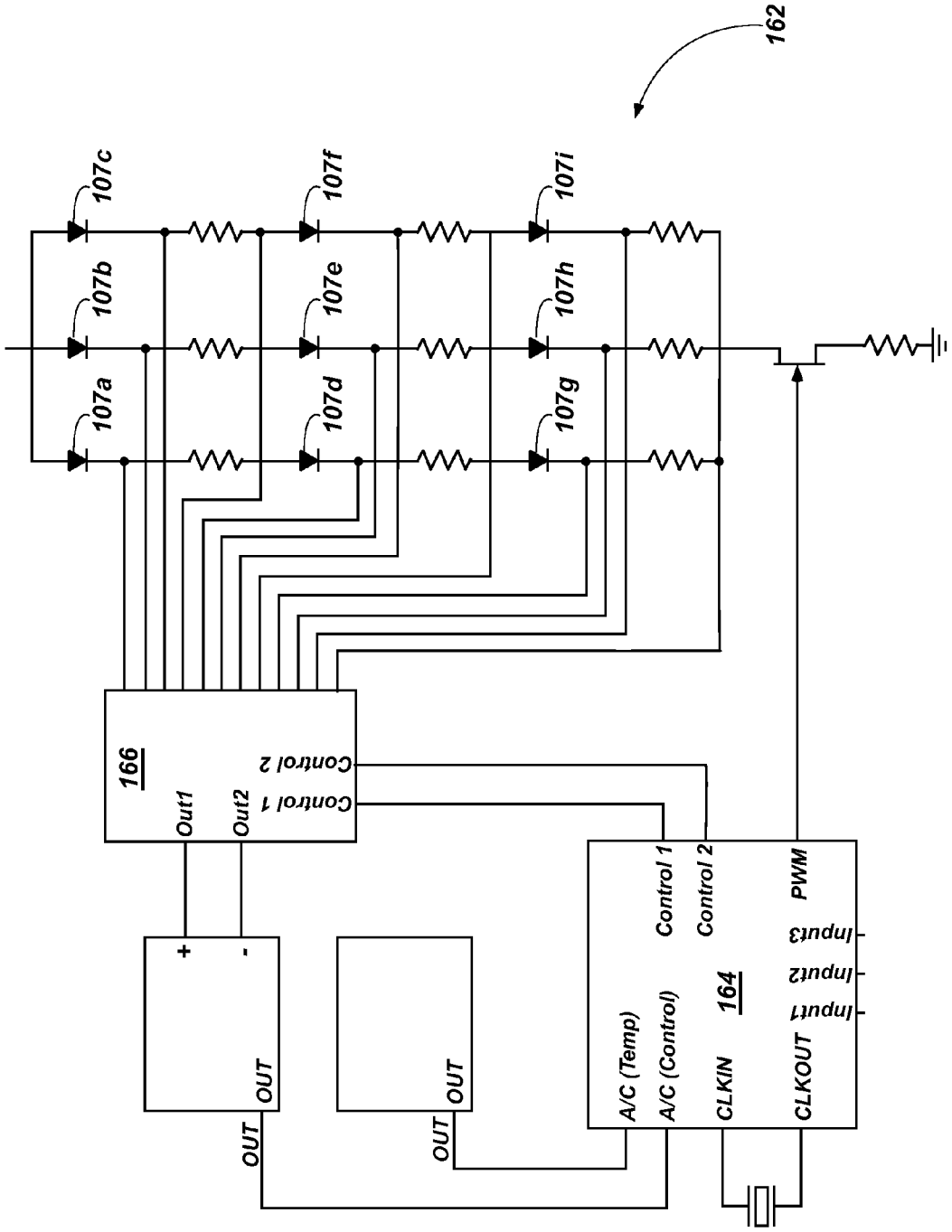
162
107c
107f
107i
107b
107e
107h
107a
107d
107g
166
Out1
Out2
Control 2
Control 1
+
-
OUT
OUT
OUT
OUT
164
Control 1
Control 2
PWM
Input3
Input2
Input1
A/C (Temp)
A/C (Control)
CLKIN
CLKOUT

FIG. 17

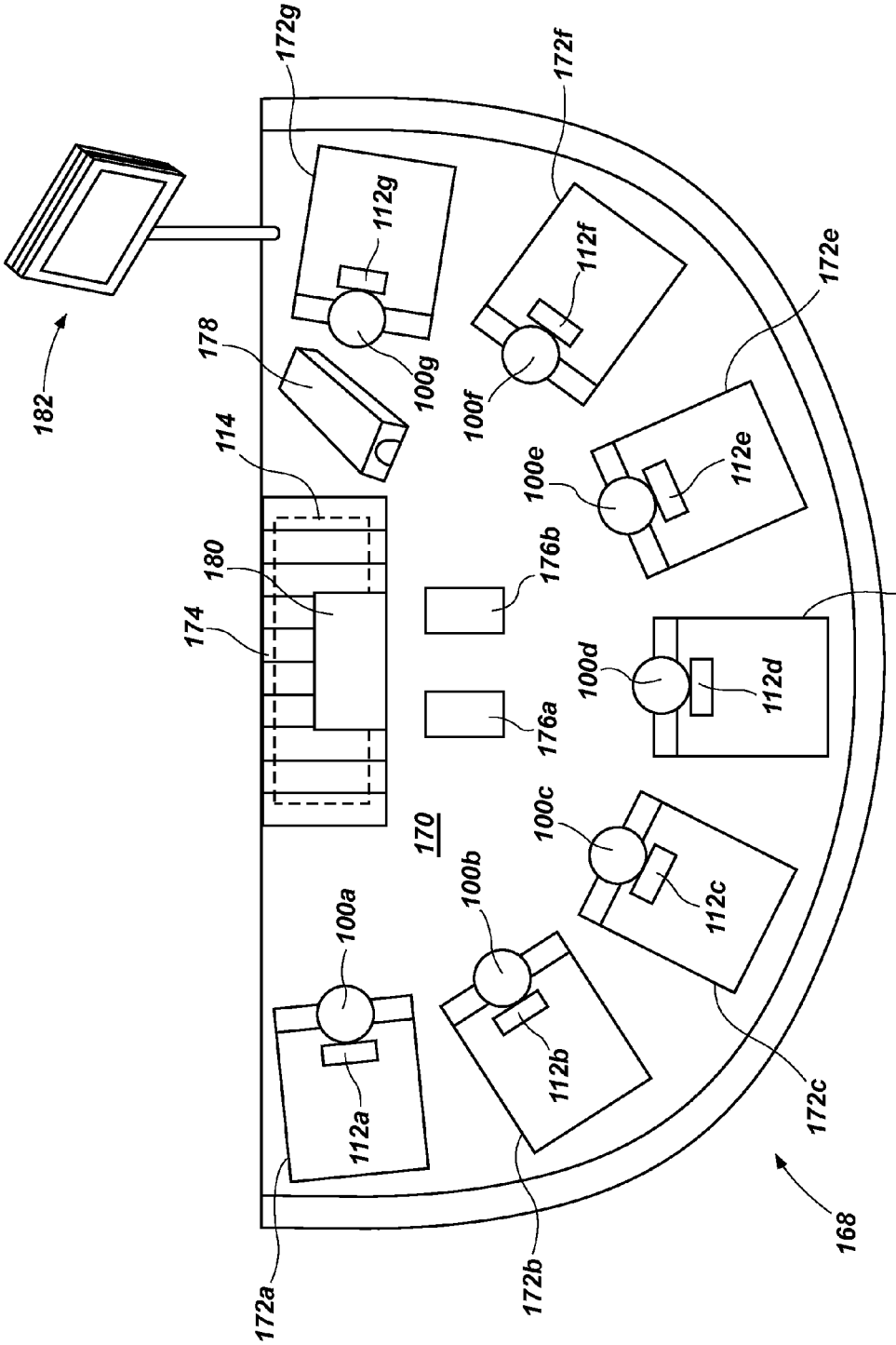
172g
172f
112g
112f
172e
178
182
100g
100f
114
112e
100e
180
176b
172d
174
100d
112d
176a
170
100c
112c
100b
100a
112b
112a
172c
168
172b
172a

FIG. 18

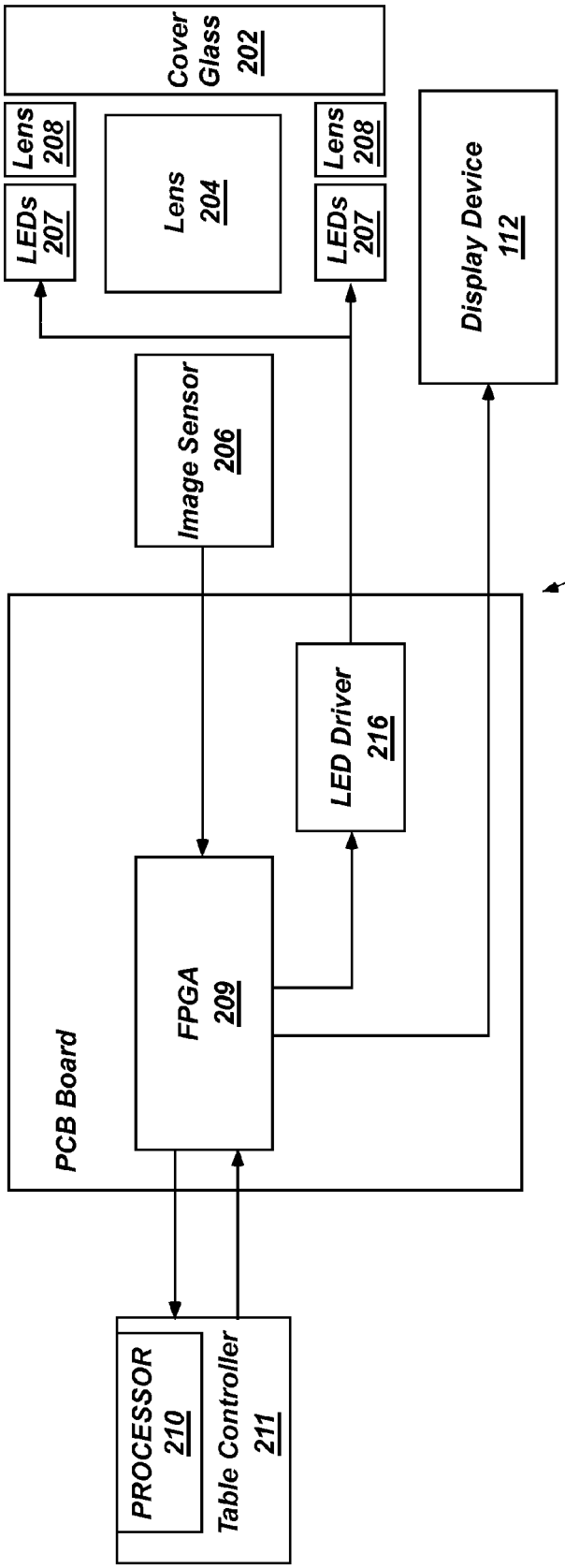
Cover Glass 202
Lens 208
LEDs 207
Lens 204
Lens 208
LEDs 207
Display Device 112
Image Sensor 206
200
LED Driver 216
FPGA 209
PCB Board
PROCESSOR 210
Table Controller 211

FIG. 19

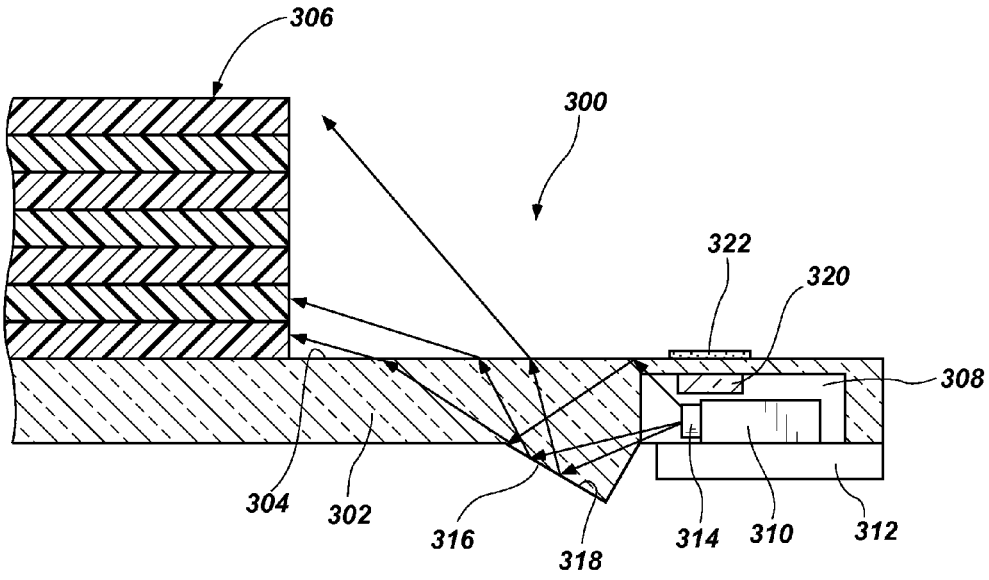

FIG. 20

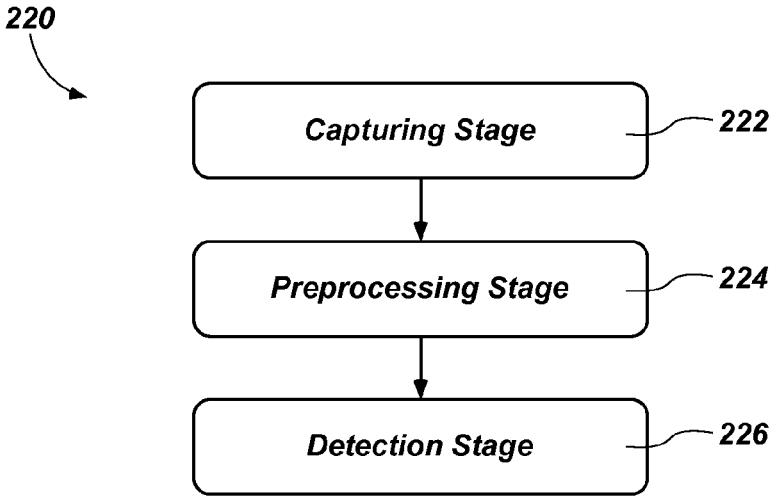
220
Capturing Stage
222
Preprocessing Stage
224
Detection Stage
226

FIG. 21

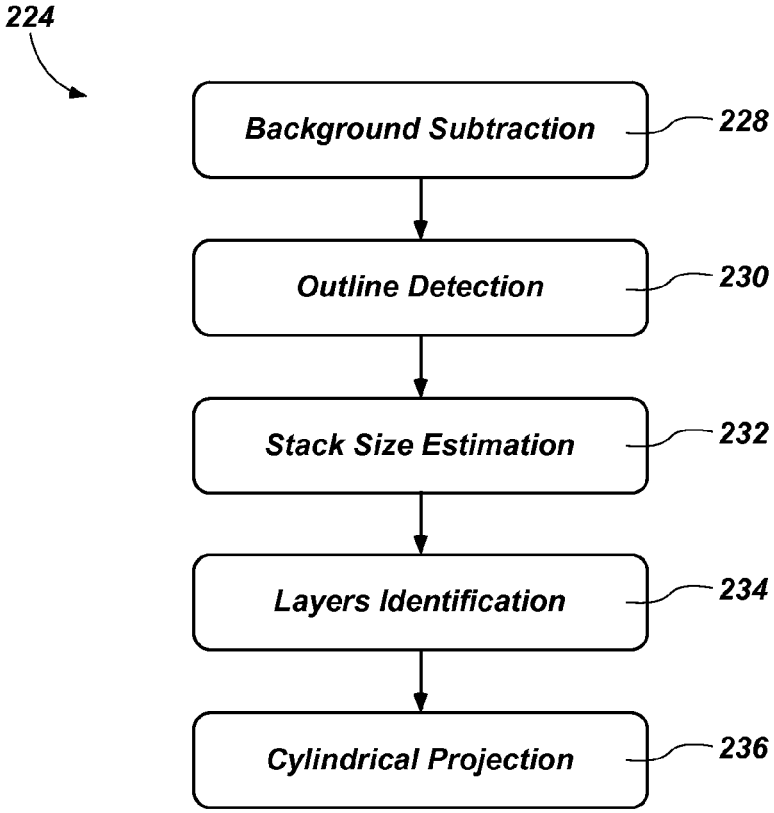
224
Background Subtraction
228
Outline Detection
230
Stack Size Estimation
232
Layers Identification
234
Cylindrical Projection
236

FIG. 22

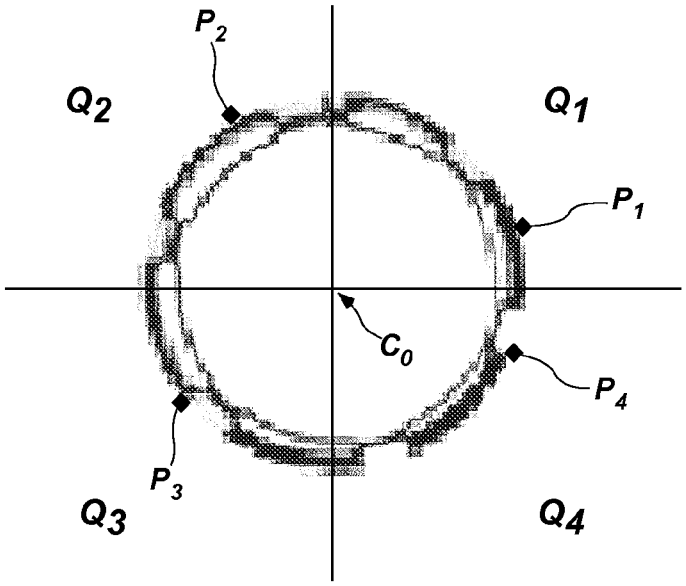

FIG. 23

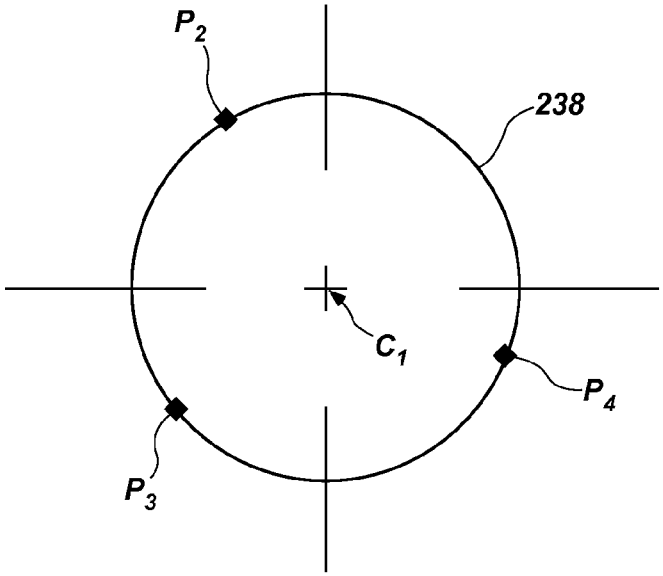

FIG. 24

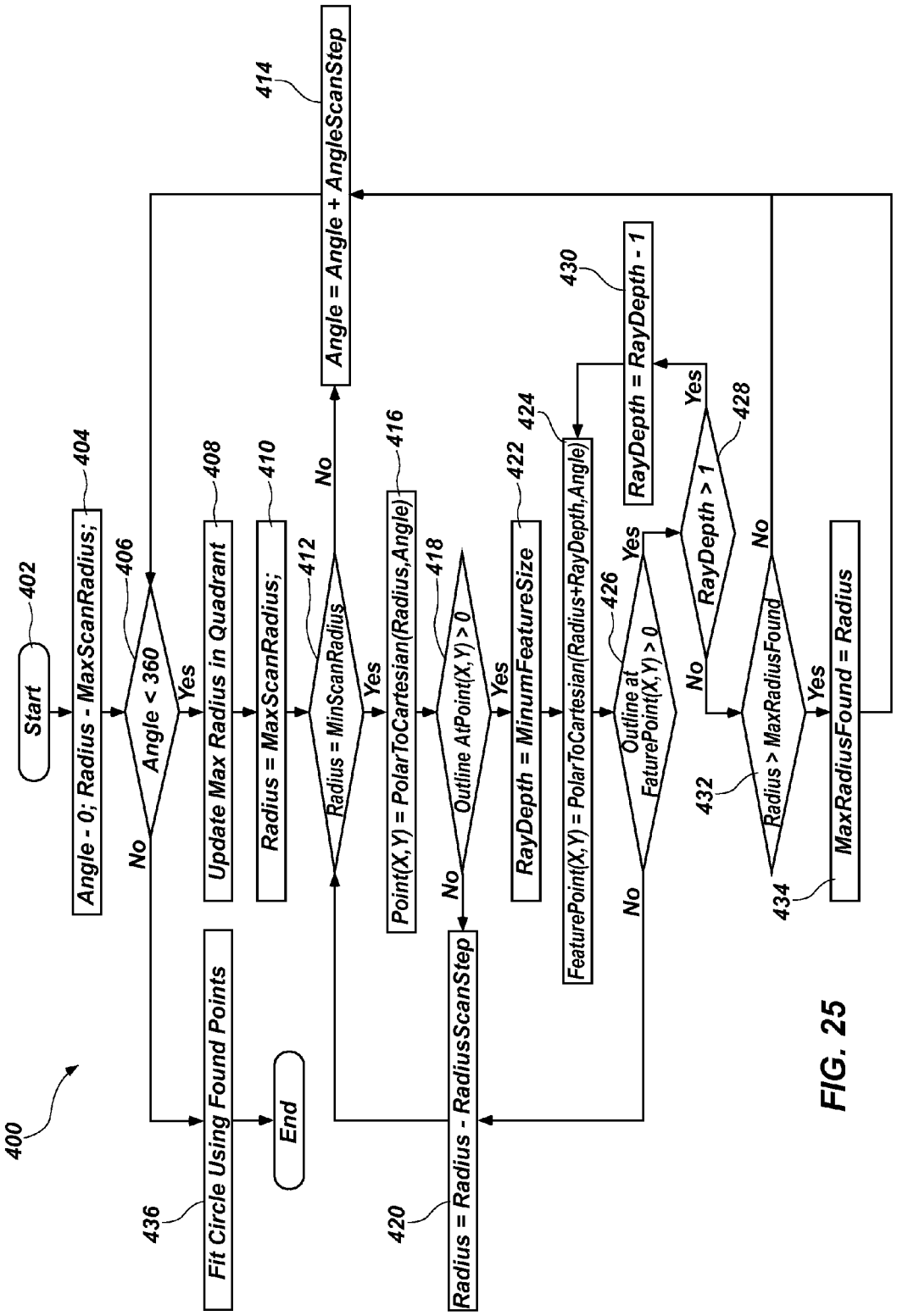
400
Start
402
Angle - 0; Radius - MaxScanRadius;
404
Angle < 360
406
No
Yes
Update Max Radius in Quadrant
408
Radius = MaxScanRadius;
410
Radius = MinScanRadius
412
No
Yes
Point(X,Y) = PolarToCartesian(Radius,Angle)
416
Outline AtPoint(X,Y) > 0
418
No
Yes
RayDepth = MinumFeatureSize
422
FeaturePoint(X,Y) = PolarToCartesian(Radius+RayDepth,Angle)
424
Outline at FaturePoint(X,Y) > 0
426
Yes
No
RayDepth = RayDepth - 1
430
RayDepth > 1
428
Yes
No
Radius > MaxRadiusFound
432
No
Yes
MaxRadiusFound = Radius
434
Angle = Angle + AngleScanStep
414
Radius = Radius - RadiusScanStep
420
Fit Circle Using Found Points
436
End

FIG. 25

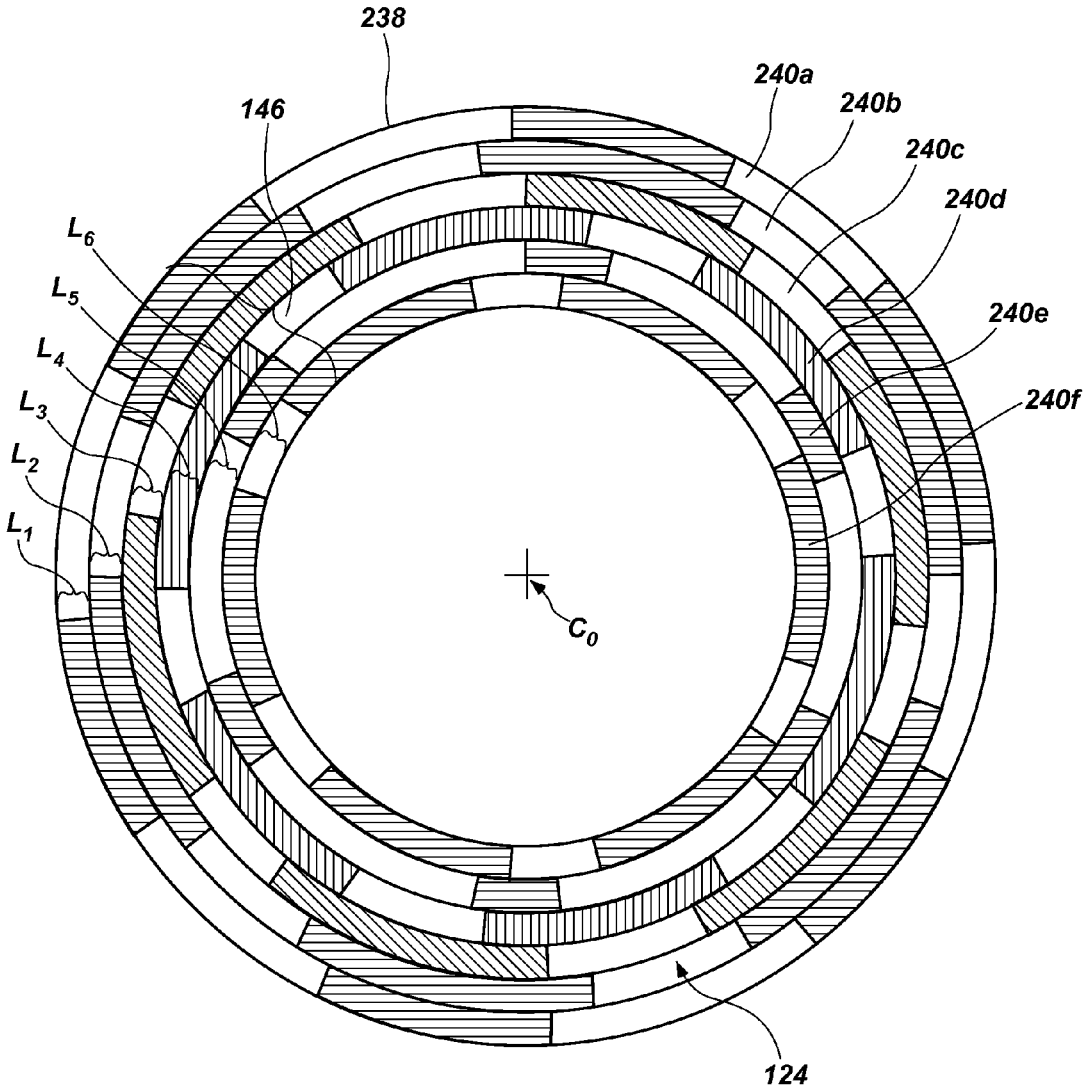

FIG. 26

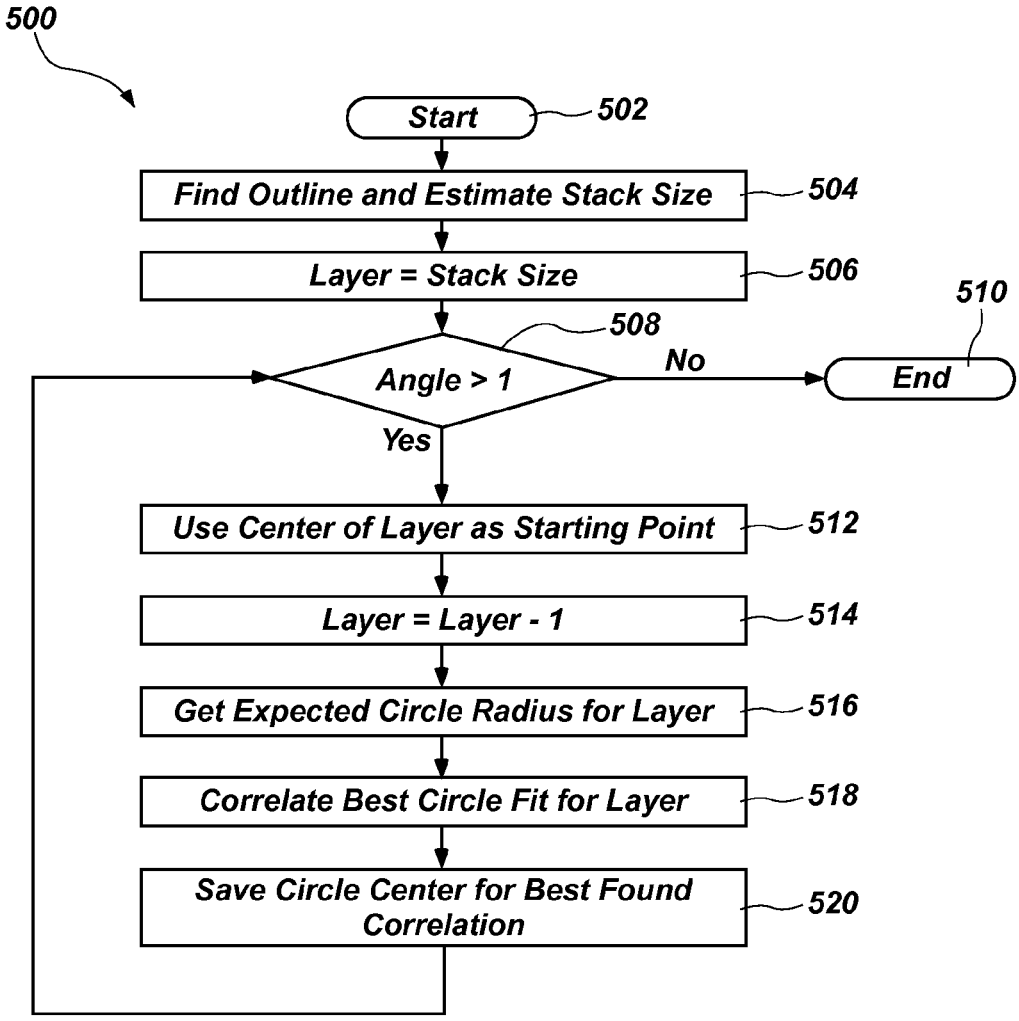
500
Start
502
Find Outline and Estimate Stack Size
504
Layer = Stack Size
506
508
Angle > 1
No
510
End
Yes
Use Center of Layer as Starting Point
512
Layer = Layer - 1
514
Get Expected Circle Radius for Layer
516
Correlate Best Circle Fit for Layer
518
Save Circle Center for Best Found Correlation
520

FIG. 27

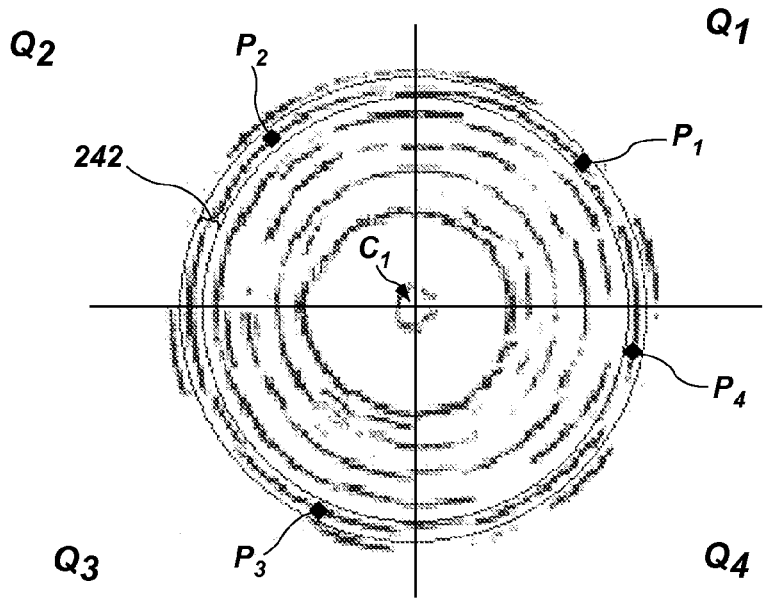

FIG. 28

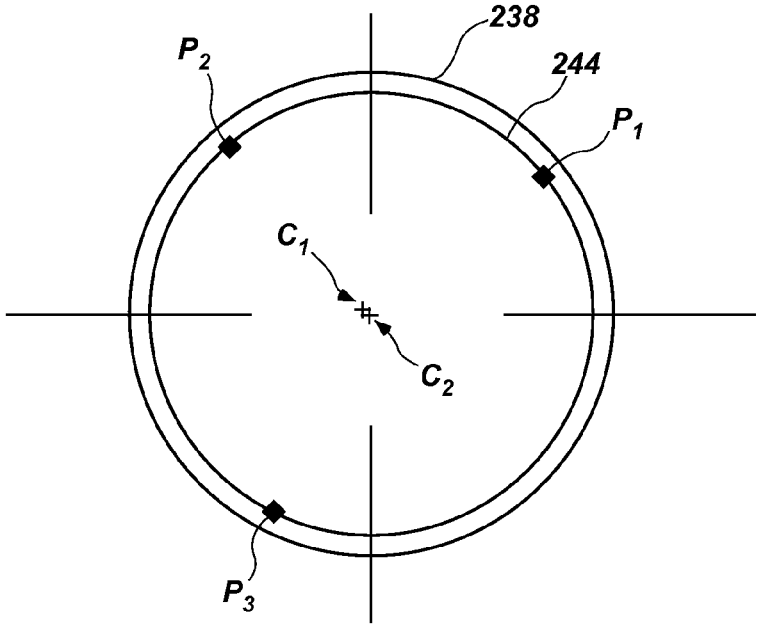

FIG. 29

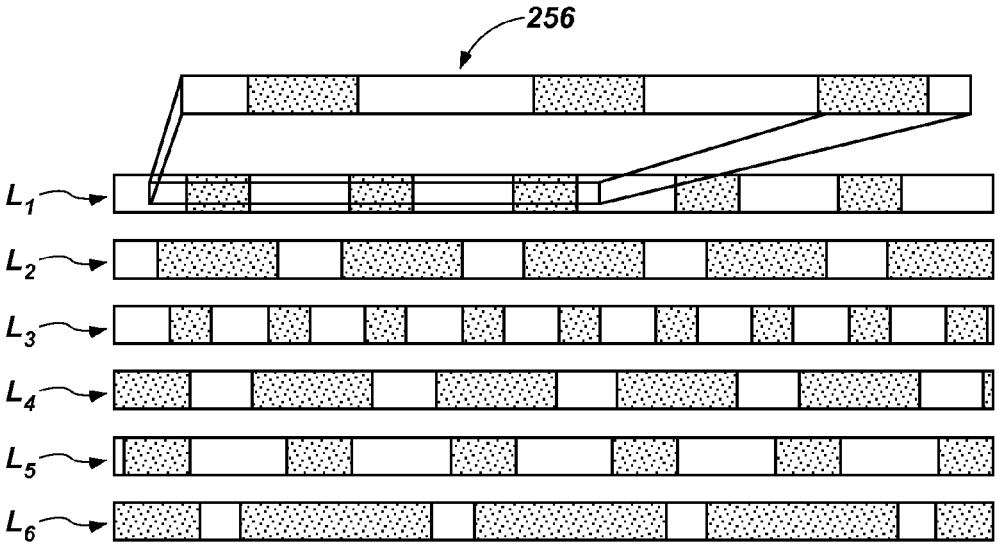
256
L1
L2
L3
L4
L5
L6

FIG. 30

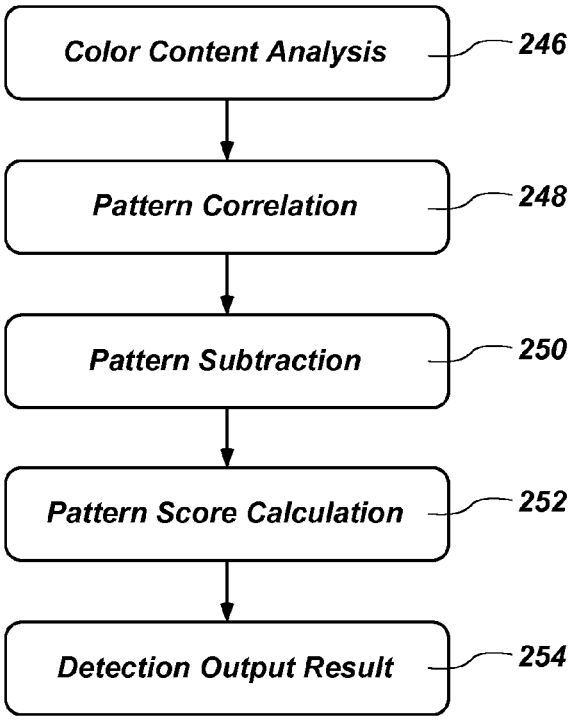
Color Content Analysis
246
Pattern Correlation
248
Pattern Subtraction
250
Pattern Score Calculation
252
Detection Output Result
254

FIG. 31

BET SENSING APPARATUSES AND METHODS

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of U.S. patent application Ser. No. 13/829,843, filed Mar. 14, 2013, now U.S. Pat. No. 8,961,298, issued Feb. 24, 2015, which claims the benefit of U.S. Provisional Patent Application Ser. No. 61/751,780, filed Jan. 11, 2013, the entire disclosure of each of which is hereby incorporated herein in its entirety by this reference.

TECHNICAL FIELD

The present disclosure, in various embodiments, relates to bet sensors for use in gaming applications, to gaming tables incorporating bet sensors, and to methods of operating such bet sensors.

BACKGROUND

In casinos and other gaming institutions, betting tables often seat up to seven players and a table operator, or dealer. Each player makes their wager by placing casino tokens on a designated location on the table. Casino tokens, also referred to as "chips," "checks," or "cheques," are small disks used by a player in lieu of currency. The tokens are interchangeable with money at the specific casino or gaming institution in which the tokens are used. It is common for casinos or other gaming institutions to provide unique tokens, each identifiable by particular colors and markings on the face and lateral side edges thereof to represent specific monetary values. The dealer is often responsible for determining the wager value of a stack of gaming tokens placed by a player.

BRIEF SUMMARY

This summary is provided to introduce a selection of concepts in a simplified form. These concepts are described in further detail in the detailed description of example embodiments of the disclosure below. This summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter.

In some embodiments, the present disclosure includes a bet sensor for sensing values of multiple gaming tokens. The bet sensor includes a bet placement surface configured and oriented to support a stack of gaming tokens thereon and an image sensor is located and oriented to capture an image of a lateral side surface of at least one gaming token located on the bet placement surface. The image depicts the lateral side surface in a radial format. The bet sensor includes a processor in communication with the image sensor. The processor is configured to acquire image data from the image and analyze the image data to determine a wager value of the at least one token.

In other embodiments, the present disclosure includes a gaming table including at least one bet sensor located proximate a surface of the gaming table. The at least one bet sensor includes a bet placement surface configured and oriented to support a stack of gaming tokens thereon and an image sensor located and oriented to capture an image of a lateral side surface of at least one gaming token located on the bet placement surface. The image depicts the lateral side surface in a radial format. In other words, each token is represented as a ring with an outer circle defining a first edge and an inner circle defining a second edge. The at least one bet sensor includes a processor in communication with the image sensor, the processor configured to acquire image data from the image and interpret the image data to determine a wager value of the at least one gaming token.

In yet other embodiments, the present disclosure includes a method of operating a gaming table having at least one bet placement surface thereon for supporting a stack of gaming tokens at a location. The method includes capturing, with an image sensor, an image of a lateral side surface of at least one gaming token at the location, wherein the lateral side surface is depicted in a radial format and converting the image, with a processor, into a converted image depicting the lateral side surface of the at least one gaming token in a form of a linear layer. The method also includes acquiring image data from the linear format of the converted image with the processor and analyzing the image data to determine a wager value of the at least one token.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a simplified schematic diagram illustrating an embodiment of a bet sensor of the present disclosure;

FIG. **2** illustrates a perspective view of a stack of gaming chips disposed on components of an embodiment of a bet sensor of the present disclosure;

FIG. **3** illustrates a side, partial cross-sectional view of the stack of gaming chips and components of the bet sensor shown in FIGS. **1** and **2**;

FIG. **4** is an enlarged view of components of the bet sensor of FIGS. **1** through **3**;

FIG. **5** illustrates a perspective view of a light-emitting diode (LED) that may be used in a bet sensor as illustrated in FIGS. **1** through **4**;

FIG. **6** illustrates a side, cross-sectional view of components of the bet sensor shown in FIGS. **1** through **4** and illustrates illumination light rays being directed onto a stack of gaming tokens on the bet sensor;

FIG. **7** illustrates a side, cross-sectional view of components of the bet sensor shown in FIGS. **1** through **4** and illustrates image light rays being directed onto an image sensor from a stack of gaming tokens on the bet sensor;

FIG. **8** illustrates a perspective view of a reflective structure having an inward-facing reflective surface that may be used in a bet sensor;

FIG. **9** illustrates a side, cross-sectional view of the reflective structure shown in FIG. **8**;

FIG. **10** illustrates a perspective view showing a top surface of a reflective structure that may be used in a bet sensor with the reflective structure shown in FIGS. **8** and **9**;

FIG. **11** illustrates a perspective view showing a reflective surface of the reflective structure shown in FIG. **10**;

FIG. **12** illustrates a side, cross-sectional view of the reflective structure shown in FIGS. **10** and **11**;

FIG. **13** illustrates a side, cross-sectional view of components of a bet sensor including the reflective structures shown in FIGS. **8** through **12**, further depicting image light rays being directed onto an image sensor from a stack of gaming tokens on the bet sensor;

FIG. **14**A illustrates a plan view of a two-dimensional image of the three-dimensional lateral side surface of a stack of gaming tokens supported on the bet sensor that may be acquired by using a bet sensor as described with reference to FIGS. **1** through **13**;

FIG. **14**B illustrates a plan view of the two-dimensional image shown in FIG. **14**A having the center of the two-dimensional image located;

FIG. **14**C illustrates a plan view of the two-dimensional image shown in FIG. **14**B having four lines superimposed over the image and extending through the center of the image;

FIG. **14**D illustrates four graphs corresponding to the four lines shown in FIG. **14**C, wherein each graph represents a plot of red pixels of the RGB color scale along one of the lines shown in FIG. **14**C;

FIG. **15** illustrates a partially cut-away perspective view of components of a bet sensor as described with reference to FIGS. **1** through **7**;

FIG. **16** illustrates a partially cut-away perspective view of a transparent cover that includes a feature configured to direct visible light signals to a player, and that may be employed in a bet sensor as described with reference to FIGS. **1** through **15**;

FIG. **17** illustrates a circuit diagram for a light-emitting diode (LED) driver that may be employed in a bet sensor as described with reference to FIGS. **1** through **16**;

FIG. **18** illustrates top plan view of an embodiment of a gaming table of the present disclosure, which includes a plurality of bet sensors as described with reference to FIGS. **1** through **17**;

FIG. **19** is a simplified schematic diagram illustrating another embodiment of a bet sensor of the present disclosure;

FIG. **20** is a side, partial cross-sectional view of components that may be employed in additional embodiments of bet sensors as described herein;

FIG. **21** illustrates a diagram of a token pattern detection algorithm, according to an embodiment of the present disclosure;

FIG. **22** illustrates a diagram of a preprocessing stage of the token pattern detection algorithm of FIG. **21**;

FIG. **23** illustrates a plan view of a two-dimensional image of the three-dimensional lateral side surface of a stack of gaming tokens utilized in the preprocessing stage of FIG. **22**;

FIG. **24** illustrates a calculated circle associated with an inner layer of the stack of gaming tokens in the image of FIG. **23**;

FIG. **25** illustrates a diagram of an algorithm for determining an outline of a stack of gaming tokens in a two-dimensional, pericentric view of the stack, according to an embodiment of the present disclosure;

FIG. **26** illustrates a plan view of a two-dimensional image of the three-dimensional lateral side surface of a stack of gaming tokens supported on the bet sensor, wherein the two-dimensional image depicts inner layers of the stack of gaming tokens;

FIG. **27** illustrates a diagram of an algorithm for identifying inner layers of a stack of gaming tokens depicted in the two-dimensional, pericentric image of FIG. **26**, according to an embodiment of the present disclosure;

FIG. **28** illustrates an edge detection image of the two-dimensional image of FIG. **26** showing layer boundaries within the stack of gaming tokens;

FIG. **29** illustrates a calculated circle associated with an inner layer of the stack of gaming tokens in the image of FIG. **28**;

FIG. **30** illustrates linear layers of a cylindrical projection of the two-dimensional image of the stack of gaming tokens of FIG. **26**; and

FIG. **31** illustrates a diagram of a detection stage of the token pattern detection algorithm of FIG. **21**.

DETAILED DESCRIPTION

The illustrations presented herein are not meant to be actual views of any particular bet sensor, gaming table, or component thereof, but are merely idealized representations that are used to describe embodiments of the disclosure.

The efficiency of a gaming table may be increased by providing a means to measure wagers of varying amounts, while reducing the amount of time required to determine the value of wagers placed during betting games played at the table. The faster wager values are calculated, the faster games may be conducted, resulting in an increase in the amount of games played at the table and, correspondingly, the amount of money wagered. Bet sensors of the present invention may be used to register wagers made on the occurrence of certain events, such as bonus events that pay large jackpots. In one example, the bet sensor can be used to register a wager on one or more progressive jackpot events that may include additional fixed payouts and or odds payout amounts. For example, a game might pay 500:1 for a Royal Flush, and the amount on the meter for the same hand. The game rules may require the first $1.00 to fund the meter, and the rest of the wager to be made against the odds payout amounts. If, for example, the meter had 15K on it when a player makes a $5.00 variable bet wager, and the player obtains a royal flush, the player wins the 15K on the meter, plus 500:1 on the other $4.00 of the bet, or $2,000. It is desirable for security reasons to provide a bet sensor that can register the bets automatically in order to assure that large jackpots are paid in the correct amounts to the players. Human table operators or dealers have limits on the speed with which they can manually determine the value of each wager placed during a betting game while also managing other aspects of the game. Bet sensors are disclosed herein that may be used to quickly determine the value of a wager placed in gaming tokens and, in some embodiments, to display the wager value to a player and/or a dealer. The bet sensor may include a mirror arrangement in proximity to a betting surface on which a stack of gaming tokens may be placed by a player. The mirror arrangement may direct a two-dimensional image of the entire circumference of the three-dimensional lateral side surface of the stack of gaming tokens onto an image sensor. A processor in communication with the image sensor may be configured under control of a computer program to perform one or more algorithms using the image to determine the value of each token in the stack of gaming tokens and to determine the sum value of the stack of gaming tokens.

FIG. **1** illustrates a simplified schematic diagram of a bet sensor **100** according to an embodiment of the present disclosure. The bet sensor **100** may include a transparent cover **102** in visual register with an optional lens **104**. The transparent cover **102** may be embedded in, or otherwise disposed proximate a gaming table (not shown in FIG. **1**) and may have a bet placement surface thereon that is configured to support a stack of gaming tokens thereon. In other embodiments, the cover may be semi-transparent and may also serve as a video display, which is described in more detail below. An image sensor **106** may be positioned to view the stack of gaming tokens through the transparent cover **102** and the optional lens **104**. An optional light source may be located proximate the transparent cover **102**. The light source may comprise one or more light-emitting diodes (LEDs) **107**, wherein the LEDs **107** are configured for

illuminating the stack of gaming tokens to provide a satisfactory image of the stack of gaming tokens to be acquired by the image sensor **106**. One or more lenses **108** may be employed with the LEDs **107** to provide desired light emission qualities. It is to be appreciated, however, that the bet sensor **100** may be configured without the optional light source, wherein an image of the stack of gaming tokens illuminated by ambient light may be transmitted to the image sensor **106**. A processor **110** may be in electronic communication with the image sensor **106** and may be configured under control of a computer program to calculate the value of the stack of gaming tokens placed as a wager on the transparent cover **102** by performing one or more algorithms using the image of the stack of gaming tokens acquired using the image sensor **106**.

The processor **110** may also be in electronic communication with a display device **112** configured to display the value of the wager to the payer who placed the wager, to other players, to a table operator, or to any combination thereof. The display device **112** may be part of the bet sensing system **100** in one embodiment and may be external to the sensing system **100** in another embodiment. The processor **110** may additionally be in electronic communication with a table controller **114** that is configured for use by the table operator. An LED driver **116** may be controlled by the processor **110**, and may comprise a circuit configured to control operational aspects of the LEDs **107**, including, by way of non-limiting example, on/off function, luminous intensity, color effects, fading, and pulse or strobe effects. In this manner, the processor **110** may control the LEDs **107** for purposes of illuminating the stack of gaming tokens, for conveying visible lighting effects or signals to players, or both. The processor **100** and at least the LED driver **116** may be located on a printed circuit board (PCB) **118**, wherein electronic communication between the processor **110** and the LED driver **116** may be provided through traces, vias, interconnects, or any combination thereof, in and/or on the PCB **118**.

FIG. **2** illustrates a stack of gaming tokens supported on an illumination unit **120** of the bet sensor **100** schematically illustrated in FIG. **1**. The illumination unit **120** is used for supporting and illuminating a stack of gaming tokens on the bet sensor **100**. As shown in FIG. **2**, the illumination unit **120** may include the transparent or semi-transparent cover **102**, which has an upper bet placement surface **122** thereon. The bet placement surface **122** may be configured and oriented to support a stack of gaming tokens **124** thereon. The transparent cover **102** may comprise any material that is sufficiently transparent to allow an image of the stack of gaming tokens to be acquired from an opposing side of the transparent cover **102** from the upper bet placement surface **122**. For example, the transparent cover **102** may comprise a ceramic material (e.g., a glass) or a polymer material (e.g., plastic, epoxy, etc.). In some embodiments, the transparent cover **102** may be tinted to reduce visibility of components of the bet sensor **100** located beneath the transparent cover **102** by players. In other embodiments, the transparent cover **102** may be replaced by a transparent or semi-transparent display such as an Active Matrix Organic Light-Emitting Diode (AMOLED). Thus, as used herein, the term "transparent" does not indicate or require transmissivity of all wavelengths of light, but only of those required for operation of the bet sensor **100**. For example, the transparent cover **102** may be configured to allow transmissivity of only certain wavelengths of light. In yet other embodiments, the transparent cover **102** may be configured to allow transmissivity of all wavelengths of visible light. In further embodiments, the transparent cover **102** may be fifty percent (50%) transparent, sixty percent (60%) transparent, seventy percent (70%) transparent, eighty percent (80%) transparent, ninety percent (90%) transparent, one hundred percent (100%) transparent, or any other degree of semi-transparency in regards to wavelengths of light required for operation of the bet sensor. The transparent cover **102** may have any suitable thickness. As a non-limiting example, the transparent cover **102** may have a thickness less than or equal to about 1.6 mm. In other embodiments, the transparent cover **102** may have a thickness between about 1.6 mm and 3.2 mm. In yet other embodiments, the transparent cover **102** may have a thickness greater than about 3.2 mm. The transparent cover **102** may be circular in shape, as shown in FIG. **2**, although other shapes may be utilized, including, by way of non-limiting example, square, rectangular, triangular, elliptical, annular, or any other shape. In embodiments where a circular transparent cover **102** is used, the diameter of the transparent cover **102** may be about 76.2 mm, although a smaller or larger diameter is within the scope of the embodiments disclosed herein. As discussed previously, the transparent cover **102** may be embedded in a gaming table, wherein the bet placement surface **122** is substantially flush with the top surface of the gaming table. In other embodiments, the transparent cover **102** may be located such that the bet placement surface **122** is positioned above or below the top surface of the gaming table. In yet other embodiments, the transparent cover **102** may be located separate from the gaming table. Moreover, it is to be appreciated that the bet sensor **100** may also be utilized in gaming applications without a gaming table.

FIG. **3** is a side, partial cross-sectional view of the illumination unit **120** of FIG. **2** and illustrates a stack of gaming tokens supported on the bet placement surface **122** of the transparent cover **102**. As shown, the transparent cover **102** may be joined to a top, planar surface **129** of a first reflective structure **130**. The transparent cover **102** and the first reflective structure **130** may be joined by screws **131**, as shown, or by alternative means, such as, by way of non-limiting example, bolts, clasps, adhesives, corresponding male and female mating components, threaded connections, other mechanical fasteners, etc. The first reflective structure **130** may comprise a frustoconical mirror having an inward-facing reflective surface **133**. The inward-facing reflective surface **133** may comprise a thin, flexible reflective film, such as a commercially available folding mirror, affixed to an inner surface of the first reflective structure **130**. Alternatively, the inward-facing reflective surface **133** may comprise a layer of reflective metal or metal alloy, such as silver, chrome, aluminum, etc., deposited on the inner surface of the first reflective structure **130**. The layer may be polished or machined in some embodiments. In yet other embodiments, the inward-facing reflective surface **133** may comprise a reflective polymeric material deposited or otherwise provided on the inner surface of the first reflective structure **130**. In still yet other embodiments, the first reflective structure **130** may be formed from a reflective metal, metal alloy, or polymeric material and the inner surface thereof may be polished to a desired level of reflectivity, or otherwise treated, to form the inward-facing reflective surface **133**. It is to be appreciated that other types of reflective materials may be utilized to provide the inward-facing reflective surface **133**. The inward-facing reflective surface **133** may be machined using a diamond turning process to a surface finish having an optical surface quality of about 60-40 scratch-dig and a surface accuracy of 1λ (λ=633.2 nanometers (nm)).

A hub structure **134** carrying a second reflective structure **136** may be centrally affixed to an underside of the transparent cover **102** by screws **138**, as also depicted in FIG. **4**. The hub structure **134** may alternatively be affixed to the transparent cover **102** by bolts, clasps, adhesives, corresponding male and female mating components, threaded connections, other mechanical fasteners, or any other means of attachment. In yet other alternative embodiments (not shown), the transparent cover **102**, the first reflective structure **130**, and the hub structure **134** may each be removably snap-fit together to provide simple assembly and disassembly of the illumination unit **120**. In still yet other embodiments, the transparent cover **102**, the first reflective structure **130**, and the hub structure **134** may be formed as a single, unitary structure in a process such as, by way of non-limiting example, injection molding or machining. Referring again to FIGS. **3** and **4**, the second reflective structure **136** carried by the hub structure **134** may comprise a generally conical-shaped mirror **140** having an outward-facing (depicted in FIG. **3** as downward-facing) reflective surface **142**. The conical mirror **140** may be concentrically and coaxially aligned with the frustoconical mirror **132** about central axis Z. The outward-facing reflective surface **142** of the second reflective structure **136** may comprise any of the materials previously described in relation to the inward-facing reflective surface **133** of the first reflective structure **130**.

With continued reference to FIGS. **3** and **4**, one or more printed circuit boards (PCBs) **144**, each carrying one or more light sources in the form of, for example, LEDs **107** thereon, may be affixed to the hub structure **134**. Each of the LEDs **107** may be configured as previously described with reference to FIG. **1**. Each LED **107** may be oriented to emit light generally radially outward from the hub structure **134** toward the inward-facing reflective surface **133** of the frustoconical mirror **132**. Each of the LEDs **107** may be located substantially on a common laterally-extending plane orthogonal to axis Z. The inward-facing reflective surface **133** may have an angle of inclination α relative to axis Z (FIG. **3**), and the outward-facing reflective surface **142** may have an angle of inclination β relative to axis Z (FIG. **4**). The angle of inclination α of the inward-facing reflective surface **133** is selected to cause light rays emitted from the LEDs **107** to reflect from the inward-facing reflective surface **133** toward and through the transparent cover **102** and onto a lateral side surface **146** of the stack of gaming tokens **124**, thus illuminating the stack of gaming tokens **124**. The angle of inclination α of the inward-facing reflective surface **133** relative to the Z axis may be in the range of about 0 degrees to about 85 degrees. In other embodiments, the angle of inclination α of the inward-facing reflective surface **133** relative to the Z axis may be in the range of about 15 degrees to about 60 degrees. In yet other embodiments, the angle of inclination a of the inward-facing reflective surface **133** relative to the Z axis may be in the range of about 30 degrees to about 40 degrees. By way of non-limiting example, the angle of inclination α of the inward-facing reflective surface **133** relative to the Z axis may be about 32.48 degrees. The angle of inclination β of the outward-facing reflective surface **142** relative to the Z axis may be in the range of about 15 degrees to about 85 degrees. In other embodiments, the angle of inclination β of the outward-facing reflective surface **142** relative to the Z axis may be in the range of about 30 degrees to about 70 degrees. In yet other embodiments, the angle of inclination β of the outward-facing reflective surface **142** relative to the Z axis may be in the range of about 50 degrees to about 60 degrees. By way of non-limiting example, the angle of inclination β of the outward-facing reflective surface **142** relative to the Z axis may be about 54.64 degrees. Refraction of the light rays may occur as they pass through the transparent cover **102**. Such refraction may be accounted for when selecting the angle of inclination α of the inward-facing reflective surface **133** to ensure that the lateral side surface of the stack of gaming tokens **124** is illuminated by the light rays after they have reflected from the inward-facing reflective surface **133** and passed through the transparent cover **102**. While FIGS. **3** and **4** illustrate each LED **107** being mounted on a separate PCB, alternatively, all of the LEDs **107** may be mounted to a single PCB **144** attached to the hub structure **134**. It is to be appreciated that in yet other embodiments, a plurality of PCBs **144** may be attached to the hub structure **134**, wherein each of the plurality of PCBs **144** carries two or more LEDs **107**.

As shown in greater detail in FIGS. **4** and **5**, each LED **107** may comprise a lens **108** or other optical component configured to provide desired light emission characteristics. The LEDs **107** may be selected based on performance characteristics, such as size, luminous intensity, emittable color spectrum, and pulse or strobe capabilities. Various LEDs suitable for use are commercially available. As a non-limiting example, the LED sold as model number LW V283 by Osram Ag. of Munich, Germany, may be used as a light source (e.g., the LEDs **107**) in embodiments of bet sensors of the present disclosure, such as the bet sensor **100**. The LEDs **107** may be relatively small. For example, FIG. **5** illustrates an LED **107***a* that may be used with the illumination unit **120**. The LED **107***a* measures about 1.9 mm at its largest dimension, L, and includes a lens **108***a* for disbursing the light rays emitted by the LED **107***a*. As will be described in more detail below, the LEDs **107** may be controlled by the processor **110** (FIG. **1**).

While FIGS. **3** and **4** illustrate two (2) LEDs **107** mounted to the hub structure **134** on opposing sides thereof, it is to be appreciated that any number of LEDs **107** may be mounted to the hub structure **134** and oriented to emit light onto the inward-facing reflective surface **133** of the frustoconical mirror **132** to be subsequently reflected through the transparent cover **102** and onto the lateral side surface **146** of the stack of gaming tokens **124**. For example, the illumination unit **120** may comprise three (3) LEDs **107** symmetrically mounted about the central axis Z along a circumference of the hub structure **134** and separated by intervals of about 120 degrees. In other embodiments, the illumination unit **120** may comprise four (4) LEDs **107** symmetrically mounted about the central axis Z along a circumference of the hub structure **134** and separated by intervals of about 90 degrees. In yet other embodiments, the illumination unit **120** may comprise five (5) or more (e.g., twelve (12)) LEDs **107**, which may be symmetrically mounted around the central axis Z along a circumference of the hub structure **134** and separated by substantially equal angular segments.

The number and orientation of the LEDs **107** mounted to the hub structure **134** may be tailored to optimize the illumination of the lateral side surface **146** of the stack of gaming tokens **124**. The upper limit on the number of LEDs **107** attached to the hub structure **134** may be determined by the size of the LEDs **107**, the size of the PCBs **144**, the size of the hub structure **134**, and the resulting number of LEDs **107** that may fit on the PCBs **144** attached to the hub structure **134**. It is to be appreciated that the LEDs **107** are not required to be oriented symmetrically about a circumference of the hub structure **134**, but may alternatively be located asymmetrically about a circumference of the hub structure **134**. Furthermore, the LEDs **107** are not all

required to be located on the same laterally-extending plane orthogonal to axis Z. In additional embodiments (not shown), the hub structure **134** may comprise two (2) or more rows of LEDs **107** mounted thereon and oriented to emit light onto the inward-facing reflective surface **133** of the frustoconical mirror **132**. In yet further embodiments, the LEDs **107** may be attached to the hub structure **134** in a random arrangement and oriented to emit light onto the inward-facing reflective surface **133** of the frustoconical mirror **132**.

It is to be appreciated that in alternative embodiments, as previously described, the bet sensor **100** may operate on ambient light only. For example, in such embodiments, the LEDs **107** and PCBs **144** may be omitted from the structures illustrated in FIGS. **3** through **7**, and ambient light rays reflected off the lateral side surface of the stack of gaming tokens may be reflected from the mirror arrangement onto the image sensor **106**.

Referring now to FIG. **7**, an image sensor **106** for acquiring images of the lateral side surface **146** of the stack of gaming tokens **124** is illustrated according to an embodiment of the present disclosure. The mirror arrangement, which includes the first reflective structure **130** and the second reflective structure **136**, is located and configured to direct an image of at least substantially an entire circumference of a lateral side surface of a stack of gaming tokens **124** supported on the bet placement surface **122** of the transparent cover **102** onto the image sensor **106**. In other words, the first reflective structure **130** and the second reflective structure **136** are sized and arranged relative to one another such that light rays R_L, including ambient light rays and/or illumination light rays emitted by the optional LEDs **107**, are reflected off the lateral side surface **146** of the stack of gaming tokens **124** through the transparent cover **102** toward the inward-facing reflective surface **133** of the first reflective structure **130**. The light rays are reflected from the inward-facing reflective surface **133** of the first reflective structure **130** toward the outward-facing reflective surface **142** of the second reflective structure **136**, from which the light rays are reflected onto the image sensor **106**.

In the embodiments illustrated in FIGS. **3**, **4**, **6** and **7**, the inward-facing reflective surface **133** of the first reflective structure **130** and the outward-facing reflective surface **142** of the second reflective structure **136** may each have a linear cross-sectional profile. In other embodiments, as illustrated in FIGS. **8** through **13**, the inward- and outward-facing reflective surfaces **133**, **142** may each have an arcuate cross-sectional profile. FIG. **8** illustrates a perspective view of the first reflective structure **130** according to such an embodiment. The first reflective structure **130** includes the inward-facing reflective surface **133** located radially inward of an outer, lateral side surface **141**, both of which are concentric about longitudinal axis Z. The first reflective structure **130** also includes a top, planar surface **129** configured to abut the transparent cover **102**.

FIG. **9** illustrates a side cross-sectional view of the first reflective structure **130** illustrated in FIG. **8** bisected by a plane containing the longitudinal axis Z of the first reflective structure **130**. When the first reflective structure **130** is viewed in a side, cross-sectional view bisecting the first reflective structure **130** through the longitudinal axis Z, as shown in FIG. **9**, the arcuate shape of directly opposing cross-sectional profiles **133***a*, **133***b* of the inward-facing reflective surface **133** may form a section of a prolate ellipse having its major axis coaxial with the longitudinal axis Z of the first reflective structure **130**. In some such embodiments, the prolate ellipse formed by the directly opposing cross-sectional profiles **133***a*, **133***b* of the first reflective structure **130** may be defined by the parameters k and R, wherein k is the conic constant of the prolate ellipse and R, in a prolate ellipse, is the radius of the prolate ellipse at a point on the prolate ellipse coincident with the major axis of the prolate ellipse. It is to be appreciated that the conic constant k determines the shape of the prolate ellipse and R determines the relative size of the prolate ellipse. Moreover, the prolate ellipse defining the directly opposing cross-sectional profiles **133***a*, **133***b* of the inward-facing reflective surface **133** may be further defined by an equation E_1, expressed as

$$z = \frac{x^2 + y^2}{R + \sqrt{R^2 - (1+k)^2(x^2 + y^2)}},$$

wherein the parameters k and R are defined as previously described, and x, y, and z represent coordinates on a three-dimensional x, y, z Cartesian coordinate system, wherein the z axis is coaxial with the longitudinal axis Z of the first reflective structure and orthogonal to the plane foamed by the x and y axes. In three-dimensional space, such as shown in FIG. **8**, the shape of the inward-facing reflective surface **133** may be defined as a prolate spheroid formed by rotating the previously described prolate ellipse through an angle of 360 degrees about its major axis. Using the x, y, z coordinate system described above, any reference point on the inward-facing reflective surface **133** may be defined in three-dimensional space by its x, y and z coordinate, wherein the x, y coordinates together define the lateral distance from axis z (and longitudinal axis Z) to the inward-facing reflective surface **133**, and the z coordinate defines the axial distance from the center of the prolate spheroid to the reference point. It is to be appreciated that, using equation E_1, the exact shape of the inward-facing reflective surface **133** may be defined. For example, if k and R are established (setting the shape and size, respectively, of the prolate spheroid, as previously described), and the z coordinate (the axial distance from the center of the prolate ellipse to the z coordinate along axis z) is established, the lateral distance (x, y) from the z axis (coaxial with longitudinal axis Z) to the inward-facing reflective surface **133** at the z coordinate can be calculated using equation E_1. Alternatively, so long as k and R are established, and the lateral distance (x, y) from the longitudinal axis Z to the inward-facing reflective surface **133** is established, the z coordinate corresponding to such lateral distance can be calculated using equation E_1.

Accordingly, in embodiments where the shape of the inward-facing reflective surface **133** is a prolate spheroid in three-dimensional space, the size and shape of the inward-facing reflective surface **133** may be adjusted by altering the variables of equation E_1. FIG. **9** illustrates a non-limiting example of the inward-facing reflective surface **133** having a shape defined by a prolate spheroid, causing the shape of the cross-sectional profiles **133***a*, **133***b* of the inward-facing reflective surface **133** to be defined by a prolate ellipse. The prolate spheroid defining the shape of the inward-facing reflective surface **133** may have parameters of k=−0.5822 and R=25.6914 mm. The inward-facing reflective surface **133** may have a maximum diameter D_1 of about 62.1 mm at coordinate (x_1, y_1, z_1), and may taper arcuately to a minimum diameter D_2 of about 41.7 mm at coordinate (x_2, y_2, z_2). The axial distance L_1, measured along axis Z, between the maximum diameter D_1 and the minimum diameter D_2, of the inward-facing reflective surface **133** may be about 15.0

mm. It is to be appreciated that the maximum and minimum diameters D_1, D_2 may be adjusted to be greater or less than 62.1 mm and 41.7 mm, respectively.

As previously described, if the shape and size of the prolate spheroid defining the inward-facing reflective surface **133** are established (by k and R, respectively), the z coordinate of the prolate spheroid can be determined along any portion of the inward-facing reflective surface **133** for which the diameter is known, such as, for example, at the maximum diameter D_1 at coordinate (x_1, y_1, z_1), at the minimum diameter D_2 at coordinate (x_2, y_2, z_2), or at any point therebetween, using equation E_1 (note that in the two-dimension space of FIG. **9**, one of the x and y coordinate would be the lateral distance between the longitudinal axis Z and the inward-facing reflective surface **133** and the other of the x and y coordinate would be zero).

FIGS. **10** through **12** illustrate a second reflective structure **136** having an outward-facing reflective surface **142** with an arcuate profile that is configured for use in a mirror arrangement with the first reflective structure **130** illustrated in FIGS. **8** and **9**. The second reflective structure **136** may include a top surface **143** and a recessed surface **145** surrounding a longitudinal aperture **147**, wherein the longitudinal aperture **147** extends coaxial with longitudinal axis Z. The longitudinal aperture may be configured to allow the image sensor **106** to view at least a bottom portion of a bottom gaming token in a stack of gaming tokens. The top surface **143** of the second reflective structure **136** may be planar and may be configured to be centrally affixed to the underside of the transparent cover **102** in a manner to be co-planar with the top, planar surface **129** of the first reflective structure **130**. In embodiments wherein the top surface **143** of the second reflective structure **136** is centrally affixed to the underside of the transparent cover **102**, the second reflective structure **136** may form the hub structure **134** previously described. In embodiments wherein the second reflective structure **136** forms the hub structure **134**, one or more PCBs **144** carrying optional LEDs **107** may be mounted to the recessed surface **145** of the second reflective structure **136**.

FIG. **12** illustrates a side, cross-sectional view of the second reflective structure **136** illustrated in FIGS. **10** and **11** bisected by a plane containing the longitudinal axis Z of the second reflective structure **136**. The outward-facing reflective surface **142** of the second reflective structure **136** may extend 360 degrees around the longitudinal axis Z of the second reflective structure **136** and may face the inward-facing reflective surface **133** of the first reflective structure **130**. As shown more clearly in FIG. **12**, the outward-facing reflective surface **142** may have opposing, convex, arcuate cross-sectional profiles **142***a*, **142***b*. By way of non-limiting example, in embodiments wherein the opposing cross-sectional profiles **133***a*, **133***b* of the inward-facing reflective surface **133** are shaped as a segment of a prolate ellipse, as shown in FIGS. **8** and **9**, each directly opposing cross-sectional profile **142***a*, **142***b* of the outward-facing reflective surface **142** may extend in an arc with a single radius R_A. By way of a further non-limiting example, if the opposing cross-sectional profiles **133***a*, **133***b* of the inward-facing reflective surface **133** are defined, as previously described, by a prolate ellipse with k=−0.5822 and R=25.6914, wherein the maximum and minimum diameters D_1, D_2 of the inward-facing reflective surface **133** are about 62.1 mm and about 41.7 mm, respectively, the outward-facing reflective surface **142** may taper arcuately from a maximum diameter D_3 of about 24.9 mm to a minimum diameter D_4 of about 9.0 mm along the opposing arcuate cross-sectional profiles **142***a*, **142***b*, wherein each cross-sectional profile **142***a*, **142***b* has a radius R_A of about 53.0 mm.

It is to be appreciated that the inward-facing reflective surface **133** of the first reflective structure **130** and the outward-facing reflective surface **142** of the second reflective structure **136** may be respectively sized, shaped, configured and oriented in any manner to direct an image of the lateral side surface **146** of the stack of gaming tokens **124** onto the image sensor **106**. For example, in alternative embodiments, the cross-sectional profiles **133***a*, **133***b* of the inward-facing reflective surface **133** of the first reflective structure **130** may be shaped as a section of a circle, oblate ellipse, parabola, hyperbola or any other shape sufficient to allow operability of the bet sensor **100**. The inward-facing reflective surface **133** may have a maximum diameter D_1 in the range of about 40.0 mm to about 250.0 mm, and may taper, linearly or arcuately, to a minimum diameter D_2 in the range of about 10.0 mm to about 100.0 mm. The inward-facing reflective surface **133** may have an axial distance L_1 in the range of about 5.0 mm to about 50.0 mm as measured along the longitudinal axis Z, between surfaces of the inward-facing reflective surface **133** at the maximum and minimum diameters D_1, D_2. The outward-facing reflective surface **142** may have a maximum diameter D_3 in the range of about 5.0 mm to about 100.0 mm, and may taper, linearly or arcuately, to a minimum diameter D_4 in the range of about 0.0 mm to about 4.0 mm. The cross-sectional profiles **142***a*, **142***b* of the outward-facing reflective surface **142** may be shaped as a section of a circle, ellipse, parabola, hyperbola, or any other shape sufficient to allow operability of the bet sensor **100**. In embodiments where the shape of the cross-sectional profiles of the inward- and outward-facing reflective surfaces **133**, **142** are defined by a portion of a conic section, such as a circle, ellipse, parabola or hyperbola, the shape-imparting conic section may be defined by a conic constant k in the range of about −8.0 to 2.0 and R in the range of about 10.0 mm to about 300.0 mm.

FIG. **13** illustrates a cross-sectional view of a mirror arrangement including the first reflective structure **130** shown in FIGS. **8** and **9** and the second reflective structure **136** shown in FIGS. **10** through **12**. Similar to the manner described above in reference to FIG. **7**, the first and second reflective structures **130**, **136** shown in FIG. **13** are sized and arranged relative to one another such that light rays R_L, including ambient light rays and/or illumination light rays emitted by the optional LEDs **107**, are reflected off the lateral side surface **146** of the stack of gaming tokens **124** through the transparent cover **102** toward the inward-facing reflective surface **133** of the first reflective structure **130**. The light rays are reflected from the inward-facing reflective surface **133** of the first reflective structure **130** toward the outward-facing reflective surface **142** of the second reflective structure **136**, from which the light rays are reflected onto the image sensor **106**. The average light ray travel distance between two components of the bet sensor **100** may be defined as the average distance a light ray may travel between the two respective components of the bet sensor **100** in a plane bisecting the concentrically-aligned inward- and outward-facing reflective surfaces **133**, **142** and containing the longitudinal axis Z thereof.

The average light ray travel distance may be determined using light ray tracer software to plot a dispersion of light rays R_L reflected off the lateral side surface **146** of the stack of gaming tokens **124** through the transparent cover **102** toward the inward-facing reflective surface **133** and reflected therefrom onto the outward-facing reflective surface **142**.

After the dispersion of light rays R_L is plotted, the average travel distance of the light rays R_L in the dispersion of light rays may be calculated between two components of the bet sensor. In the embodiment illustrated in FIG. **13**, the mirror arrangement may be sized, configured and oriented to provide an average light ray travel distance D_5 between the lateral side surface **146** of the stack of gaming tokens **124** and the inward-facing reflective surface **133** of about 26.4 mm and an average light ray travel distance D_6 between the inward-facing reflective surface **133** and the outward-facing reflective surface **142** of about 17.2 mm when the inward- and outward-facing reflective surfaces **133**, **142** are respectively sized, configured and oriented as previously described in reference to FIG. **12**. Alternatively, the mirror arrangement may be sized, configured and oriented to provide an average light ray travel distance D_5 between the lateral side surface **146** of the stack of gaming tokens **124** and the inward-facing reflective surface **133** in the range of about 15.0 mm to about 110.0 mm and an average light ray travel distance D_6 between the inward-facing reflective surface **133** and the outward-facing reflective surface **142** in the range of about 5.0 mm to about 100.0 mm.

Referring now to FIGS. **7** and **13**, an optional lens **104** or other optical components may be located between the second reflective structure **136** and the image sensor **106** and may be configured to focus or otherwise manipulate the light rays impinging on the image sensor **106** and forming an image of the stack of gaming tokens **124**. The lens **104** may comprise what is referred to in the art as a "micro video lens." In other embodiments, the lens **104** may comprise what is referred to as a "folding lens." The lens **104** may be selected based on minimum requirements of modulation transfer function (MTF) and distortion. It is to be appreciated that in some embodiments, the lens **104** may be omitted and the image may be reflected from the second reflective structure **136** directly onto the image sensor **106**. In embodiments where a lens **104** is utilized, an average light ray travel distance D_7 between the outward-facing reflective surface **142** of the second reflective structure **136** and the lens **104** may be about 16.6 mm, while an average light ray travel distance D_8 between the lens **104** and the image sensor **106** may be about 10.2 mm. In other embodiments, the average light ray travel distance D_7 between the outward-facing reflective surface **142** and the lens **104** may be in the range of about 7.0 mm and about 60.0 mm, while the average light ray travel distance D_8 between the lens **104** and the image sensor **106** may be in the range of about 5.0 mm and 50.0 mm.

The configuration of each of the first and second reflective structures **130**, **136** having a respective reflective surface **133**, **142** extending substantially entirely around a respective circumference of each of the reflective structures **130**, **136** provides a two-dimensional image on the image sensor **106** representing a 360 degree view of the entire circumference of the lateral side surface of the stack of gaming tokens on the bet placement surface of the transparent cover. Such an image may be referred to in the art as a "pericentric" or "hypercentric" image. Such an image may also be referred to as a "radial" format. In this manner, the image sensor **106** may capture a two-dimensional image representing a 360 degree view of the entire circumference of the three-dimensional lateral side surface **146** of the stack of gaming tokens **124**, as shown in FIG. **14**A. In the pericentric image of the stack of gaming tokens as shown in FIG. **14**A, the lateral side surface of each gaming token is represented as an annular shape. The annular shapes representing the lateral side surfaces of the gaming tokens are concentrically located relative to one another in the pericentric image when the chips are vertically aligned, with the annular shapes corresponding to lateral side surfaces of gaming tokens at the bottom of the stack being located closer to the center of the image and the annular shapes corresponding to lateral side surfaces of gaming tokens at the top of the stack being located at the outer radial periphery of the image.

In some embodiments, the image sensor **106** may comprise a complementary metal-oxide-semiconductor (CMOS) image sensor. The CMOS image sensor may be a color sensor or a black and white sensor and may be of the type used in a conventional CMOS camera.

As shown in FIG. **15**, the image sensor **106** may be part of an image sensor module **148** comprising a printed circuit board **118** to which the image sensor **106** is mounted. The lens **104** may mounted to the image sensor **106** on the image sensor module **148**. In some embodiments, the processor **110** of the bet sensor (**100**) may be mounted to the image sensor unit, as shown in FIG. **15**.

The image sensor **106** may be selected based on performance factors including cost, resolution, light sensitivity, and ease of integration with the processor **110**. Because most gaming tokens may be uniquely identifiable according to chip color and markings on the lateral side of the token, the illumination unit **120** (FIGS. **2** and **3**) and the image sensor module **148**, including the image sensor **106**, may be optimized to meet a basic minimum standard for image quality sufficient to allow the processor **100** to accurately recognize the color and general patterns of substantially the entire circumference of the lateral side surface of each token in the stack of gaming tokens **124**. By way of non-limiting example, the image sensor **106** may be one of a model OV9715, a model OV10620, or a model OV3642 CMOS image sensor commercially available from OmniVision Technologies Inc., of Santa Clara, Calif. By way of further non-limiting example, the image sensor **106** may be one of a model MT9V024, a model MT9D131, or a model MT9V032 CMOS image sensor commercially available from Aptina Imaging Corp., of San Jose, Calif.

Window imaging techniques may be used in connection with the image sensor **106**. For example, various window imaging sizes on the image sensor **106** may be selectively used to capture images of substantially the entire circumference of the lateral side surface **146** of the stack of gaming tokens **124**. In some embodiments, a 32 mm window diameter may be utilized in the CMOS image sensor **106**. In other embodiments, a 62 mm window diameter may be utilized in the CMOS image sensor **106**. In yet other embodiments, a 75 mm window diameter may be utilized in the CMOS image sensor **106**. In still yet other embodiments, a window diameter greater than 75 mm may be utilized in the CMOS image sensor **106**. In other embodiments, other image sensors may be utilized, such as, by way of a non-limiting example, charge-coupled device (CCD) image sensors. It is to be appreciated that any type or model of image sensor capable of capturing an image of the lateral side surface of a stack of gaming tokens is within the scope of the embodiments disclosed herein.

As described previously in reference to FIG. **1**, the image sensor **106** may be in electronic communication with the processor **110**. The processor **110** may be located on the PCB **118** proximate the image sensor module **148**. The image sensor **106** is also operatively coupled to the PCB **118** and may communicate electronically with the processor **110** through conductive vias, traces, interconnects, or a combination thereof. In other embodiments, a wire or cable may extend from the image sensor **106** directly to the processor

110. For example, an Ethernet cable or a cable extending between corresponding USB ports on or communicating with the image sensor **106** and the processor **110**, respectively, may extend between and provide communication between the processor **110** and the image sensor **106**. Alternatively, a wire or cable may extend from the image sensor **106** to an intermediate component on the PCB. In yet other embodiments, the image sensor **106** may communicate wirelessly with the processor **110**.

In addition to controlling the LEDs **107** of the illumination unit **120** (FIGS. **2** and **3**), the processor **110** may be configured under control of a computer program to control the image sensor **106** to capture images of the stack of gaming tokens **124** and transmit the images to the processor **110**. The processor **110** may be configured under control of a computer program to perform one or more algorithms using the acquired image(s) of the stack of gaming tokens **124** and to determine a sum value of the stack of gaming tokens **124** supported on the bet placement surface **122** of the transparent cover **120**. For example, the processor **110** may be configured to perforin at least two functions in the processing of images of a stack of gaming tokens **124**: token pattern calibration and token pattern detection. As previously described, the value of a single gaming token may be determined by recognizing the color and spatial patterns or markings on the lateral side surface of the token. In other embodiments, the value may be determined by color alone, markings alone or patterns alone.

The pattern calibration software and algorithms may allow a user to store in the processor memory a reference image of an entire circumference of a lateral side surface of each unique token in a set of gaming tokens. The reference image may be an image captured by the image sensor **106** of a unique token, or "reference token," placed on the bet placement surface **122** of the bet sensor **100** and illuminated by the illumination unit **120**, as previously described. The processor **110** may perform an algorithm to convert the 360 degree view of the entire circumference of the lateral side surface of the reference token into an image showing a linear depiction, which may also be characterized herein as a linear format, a linearly formatted image or a linear layer, of the entire circumference of the lateral side surface of the reference token. Once the image is converted into a linear depiction in such a manner, the processor **110** may perform an edge detection algorithm on the reference image to identify the edges of the depicted reference token. After the edges of the reference token are identified, the processor **110** may examine the areas of the token internal to the edges to identify qualities of the patterns in these areas, such as the color and size of the patterns. To do so, at least one line having a plurality of reference points may be projected through the linear depiction of the entire circumference of the lateral side surface of the reference token. The processor **110** may then perform an algorithm to identify the color intensity at each reference point on each line extending through the entire circumference of the lateral side surface of the reference token for each of the red, green and blue colors on a red blue green (RGB) color scale. After the processor **110** has identified the color intensity for each color on the RGB scale at each reference point on the line, a reference graph may be plotted and stored in the processor memory charting the color intensity for each color on the RGB scale at each reference point on the line. The processor **110** may correlate the reference graph with a unique token value previously input by an operator of the bet sensor during setup. In one embodiment, multiple lines are drawn through the pericentric image, and each line intersects a center point of the pericentric image. Histograms of the RGB values may be analyzed to locate the boundaries between chips and determine the number of chips in the stack.

The token pattern detection software and algorithms allow wager images comprising captured images of gaming tokens **124** placed by a player as part of a bet to be compared with the reference images for each token stored in the processor memory. As previously described, the image sensor **106** may transmit wager images to the processor **110**. The wager images may be continuously streamed from the image sensor **106** to the processor **110** and subsequently captured by the processor **110**, or, alternatively, the wager images may be captured by the image sensor **106** and transmitted to the processor **110**. The wager images may be stored in the processor memory while the processor **110** performs one or more algorithms to determine the value of the stack of gaming tokens **124** depicted in the wager images. The processor **110** may perform an algorithm to convert the 360 degree view of the entire circumference of the lateral side surface of the stack of gaming tokens **124** in the wager image into an image showing a linear depiction of the entire circumference of the lateral side surface of the stack of gaming tokens **124**. Once the image is converted into a linear depiction in such a manner, the processor **110** may perform an edge detection algorithm on the wager image to identify the edges of each of the depicted tokens in the stack of gaming tokens **124**. After the edges of the tokens are identified, the processor **110** may examine the areas of the tokens internal to the edges to identify qualities of the patterns in these areas, such as the color and size of the patterns. To do so, at least one line having a plurality of reference points may be projected through the linear depiction of the entire circumference of the lateral side surface of each token in the wager image, according to the manner previously described with respect to the reference image, to obtain a token graph charting the color intensity for each color on the RGB scale at each reference point on the line for each token in the wager image. Subsequently, the processor may compare the token graph for each token in the wager image to each reference graph stored in the processor memory until the processor identifies the stored reference graph having RGB color intensity characteristics most closely corresponding to each token graph. The processor **110** may then add the unique token values derived for each token in the wager image to calculate a sum wager value of the stack of gaming tokens **124** depicted in the wager image. It is to be appreciated that such processes and algorithms performed by the processor **110** to obtain token graphs for each token in a wager image will result in a high degree of accuracy regardless of whether the stack of gaming tokens **124** wagered by a player is illuminated by the illumination unit **120** or by ambient light only.

In one potential alternative method, after the wager image is captured and transmitted to the processor **110** by the image sensor **106**, the processor **110** may utilize software to extract data from the pericentric wager image for comparison with data of reference images for each token stored in the processor memory. Referring now to FIG. **14**B, pixel data present in the wager image may be used to extract information about the gaming tokens **124** displayed therein. For example, if the center C of the pericentric wager image has been located, it is to be appreciated that a number of lines extending through the center C will pass through the lateral side surfaces (or pericentric "rings") of the gaming tokens **124** illustrated in the wager image. The lines may also pass through the various colored regions of the rings in the wager

image. FIG. **14**C illustrates the wager image of FIG. **14**B having four (4) lines W_1, W_2, W_3, W_4 extending through the center C of the wager image and passing through the rings, including the various colored portions. The pixel data contained in the wager image may include the color on the RGB color scale of the pixels intersected by each of the lines W_1, W_2, W_3, W_4.

Referring now to FIG. **14**D, a plot of four (4) graphs is illustrated representing plots of red pixels of the RGB color scale along each of the lines W_1, W_2, W_3, W_4. As shown in FIG. **14**D, the x-axis of each plot represents the distance from the center C of the pericentric wager image along each line, and the y-axis represents the ratio of red pixels to green or blue pixels intersected by the line at a given reference band centered at each respective reference point along the x-axis. In this manner, each plot provides an indication of the varying degrees to which the image appears red along the x-axis. At locations along the x-axes corresponding to locations of the wager image where the respective line intersects the transition between the ring of a first gaming token and the ring of a second, adjacent gaming token, the corresponding value on the y-axes will transition from one substantially constant red value representing the first ring to another substantially constant red value representing the second, adjacent ring.

It is to be appreciated that if the x-axes of the plots for each of the lines W_1, W_2, W_3, W_4 are aligned, with the center C of the pericentric image located at the origin of the x-axes, the transition points in the y-values of the plots will also be aligned at corresponding x-values in each of the plots, shown in FIG. **14**D as boundaries B_1-B_8. The transition points on the graphs correspond to the boundaries between adjacent rings in the wager image. The first boundary B_1 represents the edge of the colored marking on the underside of the lowermost, or "first," gaming token in the stack of gaming tokens along the lines W_1, W_2, W_3, W_4; the second boundary B_2 represents the transition from the underside to the lateral side surface of the first gaming token; the third boundary B_3 represents the transition between the lateral side surface of the first gaming token to the lateral side surface of a second gaming token, and so forth, and the last boundary, shown as B_8 in FIG. **14**D, represents the top edge of the lateral side surface of the uppermost, i.e., "top" or "last," gaming token in the stack of gaming tokens **124**. In this manner, by aligning the plots and plotting the boundaries between adjacent gaming tokens through the x-axis of each graph, each distinct ring in the wager image may be identified from the regions on the x-axes located between adjacent boundaries of the boundaries B_1-B_8.

Once each distinct ring in the wager image is identified as a region on the x-axes located between adjacent boundaries of the boundaries B_1-B_8, the degree of redness of each boundary, represented by the y-values, may be extrapolated for comparison to corresponding data extrapolated from the reference images for each gaming token **124** stored in the processor memory. It will be appreciated that the accuracy of the comparison is increased as the number of lines extending through the center C of the wager image is increased. After each distinct ring in the wager image is identified as a corresponding region on the x-axes located between adjacent boundaries of the boundaries B_1-B_8, the total number of red pixels within each ring intersected by each of the lines W_1, W_2, W_3, W_4 may be calculated to acquire a total red pixel value for each ring. In a similar manner, separate green and blue RGB graphs along each of lines W_1, W_2, W_3, W_4 may be plotted and aligned to acquire a total green pixel value and a total blue pixel value for each ring. The total red, green, and blue pixel values for each ring may be combined to acquire a wager RGB signature for each ring. The wager RGB signature for each ring may then be compared to corresponding RGB signatures of gaming tokens **124** depicted in reference images until the stored RGB signature that most closely corresponds to the wager RGB signature for each ring is identified. In this manner, pixel data from the wager image may be extracted and manipulated for comparison with reference images previously stored.

The processor **110** may be configured to run software to extract and manipulate data in the wager image for comparison with reference image data stored in the processor memory. For example, the processor **110** may run pattern recognition software, including, by way of non-limiting example, edge detection software, as is known in the art, to locate the center C of the pericentric wager image. After the center C of the pericentric wager image is located, pixel data, including RGB pixel color or intensity, along lines extending through the center C of the wager image may be acquired by the processor **110**. Such pixel data may include the pixel data for the various colored regions of the rings in the wager image. The processor **110** may utilize the acquired pixel data to further identify the boundaries between adjacent rings in the pericentric wager image. Once the boundaries between adjacent rings are identified, the processor **110** may organize the acquired pixel according to each ring in the wager image to acquire a pixel data signature for each ring. The pixel data signature for each ring in the wager image may include an RGB pixel signature for each ring. The processor **110** may then compare the pixel data signature for each ring in the wager image with corresponding pixel data signatures for the reference images stored in the processor memory until the processor **110** identifies the reference image with the pixel data signature most closely corresponding to the pixel data signature of each respective ring in the wager image. Subsequently, the processor **110** may assign to each ring in the wager image a wager value associated with the corresponding stored pixel data signature. The processor **110** may then add the wager values assigned to each ring in the wager image to calculate a sum wager value of the stack of gaming tokens **124**.

Alternatively, the reference image for each unique token may comprise a composite image of the entire circumference of the lateral side surface of the token. In some embodiments, the composite image may be derived from at least two base images stored in the processor memory, including at least one base image of the token illuminated by ambient light and at least one base image of the token illuminated by the illumination unit **120**. The stored base images for each unique token may be processed to form a single grayscale composite image of the token in the processor memory. The composite image may be further processed and assigned a composite value by the processor. To derive the composite value for each composite image, according to one non-limiting example, the processor **110** may perform an edge detection algorithm on the composite image to identify the edges of the depicted token. After the edges of the token are identified, the processor **110** may examine the areas of the token internal to the edges to identify qualities of the patterns in these areas, such as the shape, size, and grayscale shade of the patterns. Subsequently, the processor **110** may assign the image a reference designation derived from processing a set of sub-values, the set of sub-values comprising a sub-value for each of at least the processed shape, size, and grayscale shade qualities of the internal areas of the depicted token. The reference designation may comprise a single value derived from

processing the set of sub-values, or, alternatively, may comprise a listing of the set of sub-values. The processor **110** may correspond the reference designation with a unique token value previously input by an operator of the bet sensor **100** during setup. The unique token value may be equivalent to the actual monetary value of the token.

In other embodiments, a single base image, taken under ambient light, of substantially the entire lateral side surface of each unique token may be stored in the processor memory. In such embodiments, the stored base image may be further processed to form a corresponding second base image altered to represent an image of the unique token illuminated by the illumination unit **120**. Thus, the stored base images for each unique token may be processed to form a single grayscale composite image of the unique pattern on the lateral side surface of the associated token. The composite image may then be stored in the processor memory. In such an embodiment, the token depicted in the composite image may be further processed and assigned a unique token value, as previously described.

In yet other embodiments, a single base image, taken under light emitted by the illumination unit **120**, of substantially the entire lateral side surface of each unique token may be stored in the processor memory. In such embodiments, the stored base image may be further processed to form a corresponding second base image altered to represent an image of the unique token illuminated only by ambient light. Thus, the stored base images for each unique token may be processed to form a single grayscale composite grayscale image of the unique pattern on the lateral side surface of the associated token. The composite image may then be stored in the processor memory. In such an embodiment, the token depicted in the composite image may be further processed and assigned a unique token value, as previously described.

In further embodiments, a single base image, taken either under ambient light or light emitted by the illumination unit **120**, of substantially the entire lateral side surface of each unique token may be stored in the processor memory and may be further processed to store in the processor memory a grayscale reference image of the unique pattern on the lateral side surface of the associated token. The token depicted in the grayscale reference image of such an embodiment may be further processed and assigned a unique token value, as previously described. It is to be appreciated that any method of storing in the processor memory an image of the unique pattern on the lateral side surface of an associated token is within the scope of the embodiments of the present disclosure.

As previously described, the token pattern detection software and algorithms allow wager images comprising captured images of gaming tokens **124** placed by a player as part of a bet to be compared with the reference images for each token stored in the processor memory. The processor **110** may convert each wager image into grayscale and subsequently perform an edge detection algorithm to identify the edges of the depicted token, as described previously. After the edges of each token in the wager image are identified, the processor **110** may examine and process the areas of each token internal to the edges thereof to identify one or more of the shape, size, and grayscale shade of the patterns within the edges of the depicted tokens. Subsequently, the processor **110** may assign each token depicted in the wager image a token designation derived from processing a set of sub-values, the set of sub-values comprising a sub-value for one or more of the processed shape, size, and grayscale shade qualities of the internal areas of the depicted token. The token designation may comprise a single value derived from processing the set of sub-values, or, alternatively, may comprise a listing of the set of sub-values. The processor **110** may then compare the token designation with the reference designations stored in the processor memory until the processor identifies the stored reference designation most closely corresponding to the token designation. Subsequently, the processor **110** may associate the token designation with the unique token value stored in association with the corresponding reference designation. The processor **110** may then add the unique token values derived for each token in the stack of gaming tokens **124** to calculate a sum wager value of the stack of gaming tokens **124**.

Referring now to FIG. **21**, a token pattern detection algorithm **220** is shown according to an example embodiment of the present disclosure. The algorithm may include three (3) stages: a capturing stage **222**, a preprocessing stage **224**, and a detection stage **226**. In the capturing stage **222**, pericentric images of the circumference of the lateral side surface **146** of the stack of gaming tokens **124** are acquired by the image sensor **150** and converted to a predetermined image format for further processing during the preprocessing stage **224**. In the preprocessing stage **224**, the pericentric images may be processed to identify layers therein representing the lateral side surfaces of individual tokens within the stack and to convert each of the layers into a linear orientation, which may also be characterized as a format, for further processing. In the detection stage **226**, the processor **110** may identify and correlate patterns within each linear layer of the stack with known patterns stored in the processor memory.

During the capturing stage **222**, the image sensor **150** may capture and transmit an image of the circumference of the lateral side surface **146** of the stack of gaming tokens **124** using a video capture and output program in combination with a camera driver and media controller architecture. By way of non-limiting example, the image sensor **150** may be an Aptina sensor patched to run a Linux distribution operating system. The video capture and output program may be Video for Linux 2 (also known as "V4L2"). In this example, the processor **110** may include a BeagleBoard processing platform operating the V4L2 program, the camera driver, and the media controller architecture on Linux distribution. The camera driver may be configured to limit the output image to a region of interest containing substantially only the lateral side surface of the stack of gaming tokens. The media controller architecture configured as described above may output the image in a raw 12-bit BGGR Bayer format. The processor **110** may operate the V42L program and media controller to convert the 12-bit BGGR Bayer format image to a 12-bit RGB for rat image and further convert the 12-bit RGB format image into an 8-bit RGB format image.

In some embodiments, the processor **110** may effectively synchronize the capture of images by the image sensor **150** with illumination of the lateral side surface **146** of the stack of gaming tokens **124** by the illumination unit **120** by identifying the illumination intensity of the captured images and deleting or otherwise removing those images having an illumination intensity falling below a predetermined threshold.

FIG. **22** illustrates a flowchart of a method performed on captured images at the preprocessing stage **224**. In the preprocessing stage **224**, pericentric images of the circumference of the lateral side surface **146** of the stack of gaming tokens **124** captured by the image sensor **150** and formatted by the media controller are manipulated to generate images that are suitable for pattern correlation by the processor **110**. The preprocessing stage **224** may include a background

subtraction act **228**, an outline detection act **230**, a stack size estimation act **232**, a layer identification act **234**, and a cylindrical projection act **236**, each as set forth more fully below.

In the background subtraction act **228**, the image sensor **150** may capture background images directed onto the image sensor **150** by the mirror arrangement when no gaming tokens are present on the bet placement surface **122**. The processor **110** may identify elements in the background images taken when no gaming tokens are present on the bet placement surface **122** as background elements. The processor **110** may then remove the background elements from the pericentric images of the lateral side surface **124** of the stack of gaming tokens **146** captured by the image sensor **150**, wherein the processor **110** outputs a background-subtracted image depicting substantially only the lateral side surface **124** of the stack of gaming tokens **146** to a frame buffer in the processor memory for further processing. The background images may be captured randomly by the image sensor **150** or at a predetermined schedule, such as when the bet sensor is turned "on." In some embodiments, the background images may be captured between successive bet placements. The background-subtracted image may be further processed to form a thresholded image for use in subsequent acts of the preprocessing stage **224**.

In the outline detection act **230**, the processor **110** may identify the effective center, or "ideal center," C_0 of the pericentric view of the stack of gaming tokens **124** depicted in the thresholded. In some embodiments, the processor **110** may identify the ideal center C_0 of the pericentric view of the stack of gaming tokens **124** as coincident with the Z-axis of the mirror arrangement.

Referring now to FIG. **23**, a thresholded image of the lateral side surface **146** of a stack of gaming tokens **124** is shown narrowed to a region of interest containing substantially only the lateral side surface **146** of the stack of gaming tokens **124**. A circular outline of the pericentric lateral side surface **146** of the stack of gaming tokens **124** is extrapolated by identifying radially-outermost, non-zero points in the thresholded image measured from the ideal center C_0 of the stack of gaming tokens **124**. By way of non-liming example, the region of interest may be divided into four (4) quadrants, with the first quadrant Q_1 extending from 0 degrees to 90 degrees, the second quadrant Q_2 extending from 90 degrees to 180 degrees, the third quadrant Q_3 extending from 180 degrees to 270 degrees, and the fourth quadrant Q_4 extending from 270 degrees to 360 degrees (0 degrees). The processor **110** may identify, in each of the four quadrants Q_1-Q_4, a radially-outermost non-zero point P_1, P_2, P_3, P_4. After these points P_1, P_2, P_3, P_4 are identified, the processor **110** may then select the radially-outermost non-zero point of three (3) of the four (4) quadrants to perform a circle fit function to form a circle representing a circular outline **238** of the pericentric view of the stack of gaming tokens **146** in the thresholded image. The processor **110** may optionally select the three radially-outward-most non-zero points with the greatest angular distance therebetween to perform the circle fit function. As shown in FIG. **23**, the three radially-outward-most non-zero points with the greatest angular distance therebetween are P_2, P_3 and P_4. After these three (3) points P_2, P_3, P_4 are selected, as shown in FIG. **24**, the processor **110** may perform the circle fit function by forming a circle intersecting each of the three (3) selected points P_2, P_3, P_4, which circle represents the circular outline **238** of the stack of gaming tokens depicted in the pericentric, thresholded image previously described. The processor **110** may also identify and log the center C_1 of the circular outline **238**.

FIG. **25** illustrates a non-limiting example of an algorithm **400** for identifying radially-outermost points in each quadrant, according to an embodiment of the present disclosure. In the algorithm **400**, the processor **100** may proceed to scan, at a start angle (in the present example, the start angle is 0 degrees), radially inward, along a radial line intersecting the ideal center C_0 of pericentric, thresholded image, from a maximum scan radius (i.e., "MaxScanRadius") to a minimum scan radius (i.e., "MinScanRadius") to identify non-zero points along this line. Once the processor **110** has completed its scan at the start angle, the processor may repeat the scan at a second angle, wherein the second angle is greater than the start angle by an incremental angle (i.e., "AngleScanStep"). The processor **110** may repeat the process until it has repeated the scans at angles from 0 degrees to 360 degrees of the thresholded image.

At the start **402** of the algorithm **400**, the start angle may be set at 0 degrees and the processor **110** may begin scanning at the MaxScanRadius radially inward to the MinScanRadius. The MaxScanRadius and the MinScanRadius may be predetermined by the processor **110**. At act **406**, the processor **110** may identify the angle at which it is performing the scan. If the angle is less than 360 degrees (i.e., the entire 360 degree region of the image has not been scanned), the processor **110** may proceed to act **408**, wherein the processor **110** may update the maximum radius identified at any of the previously scanned angles prior to continuing to scan from the MaxScanRadius radially inward to the MinScanRadius at the present angle. If, during this scan, the processor **110** identifies a non-zero point (i.e., a pixel) in the thresholded image, the processor **110** may determine, at act **412**, whether the non-zero point is located at a radius greater than the MinScanRadius. If the non-zero point is not located at a radius greater than the MinScanRadius, or if no non-zero point is located between the MaxScanRadius and the MinScanRadius, the processor **110** may proceed to act **414**, wherein the processor **110** may perform the scan at the next angle increased in the amount of the AngleScanStep. However, if a non-zero point is located during act **412** between the MaxScanRadius and the MinScanRadius, the processor may proceed to act **416**, wherein the processor **110** may log the location of the non-zero point as a Cartesian coordinate (x, y).

After logging the non-zero point, the processor **110** may determine whether the non-zero point represents a feature of the thresholded image or mere noise present in the image. To make such a determination, the processor may determine, at act **418**, whether a pixel is present at the logged coordinate (x, y). If no pixel is present at the logged coordinate (x,y), the processor **110** may continue scanning radially inward to the MinScanRadius, as shown at act **420**. However, if a pixel is present, the processor **110** may then explore the depth of the feature identified at the non-zero point at coordinate (x, y). At act **422**, the processor **110** may recall a predetermined ray depth (i.e., "RayDepth"), measured from the logged coordinate (x, y), representing a minimum feature size (i.e., "MinumFeatureSize") necessary for the processor **110** to identify the feature as a portion of the stack in the thresholded image instead of mere noise present in the image. By way of non-limiting example, the RayDepth may have a width of four (4) pixels. The processor **110** may initiate a decrementing process through which the depth of the feature is iteratively measured to determine whether the depth is greater than the MinFeatureSize. At act **424**, the processor

110 may identify a feature point (i.e., "FeaturePoint") located a distance of RayDepth from the logged coordinate (x, y). At act 426, the processor 110 may determine whether a pixel is present at the FeaturePoint. If a pixel is not present at the FeaturePoint, the processor 110 may continue scanning from the non-zero point radially inward to the MinScanRadius, as shown at act 420. However, if a pixel is present at the FeaturePoint, the processor 110 may identify whether the RayDepth has a size greater than 1 pixel at act 428. If the RayDepth is greater than one (1) pixel, the processor 110 may reduce the size of the RayDepth by one (1) pixel at act 430 and repeat acts 424 and 426 with the reduced RayDepth. Acts 424, 426, 428 and 430 may be repeated until the RayDepth is decremented to zero. The number of iterations through acts 424, 426, 428 and 430 allows the processor 110 to apprise the depth of the non-zero point to determine whether the non-zero point represents image noise or a portion of the stack in the thresholded image. The iterative process of acts 424, 426, 428 and 430 may end if, at act 428, the processor 110 identifies the size of the iteratively decremented RayDepth as being equal to or less than one (1) pixel. It is to be appreciated that if acts 424, 426, 428 and 430 are repeated until the processor 110 identifies the size of the RayDepth as being equal to or less than one (1) pixel at act 428, the depth of the non-zero point will have been determined by the processor 110 to have been greater than the MinimumFeatureSize, and thus determined to be a portion of the stack depicted in the thresholded image instead of mere noise present in the image.

If, at act 428, the processor 110 identifies the size of the RayDepth as being equal to or less than one (1) pixel, the processor 110 may then determine, at act 432, whether the radius at the non-zero point is greater than the maximum radius found (i.e., "MaxRadiusFound") at any of the preceding angles scanned within the present quadrant. If the radius at the non-zero point is not greater than the MaxRadiusFound within the present quadrant, the processor 110 may proceed to act 414 to perform the scan at the next angle increased by the AngleScanStep. However, if the radius at the non-zero point is greater than the MaxRadiusFound within the present quadrant, the processor 110 logs, at act 434, the radius at the non-zero point as the MaxRadiusFound within the present quadrant prior to proceeding to act 414 to perform the scan at the next increased by the AngleScanStep. After increasing the angle by the AngleScanStep, the processor 110 proceeds to act 406 to determine whether the present angle is less than 360 degrees, and if so, proceeds to acts 408 and beyond at the present angle. The process is repeated until the processor 110 has logged the radially-outeinost points in each of the quadrants and, at act 408, determines that the present angle is equal to or greater than 360 degrees, at which point the processor 110 proceeds to act 436, wherein the processor 110 performs the circle fit function with the three radially-outermost points that have the greatest angular distance therebetween, as previously described. Once the circle fit function has produced the circular outline 238 of the pericentric view of the stack of gaming tokens 124 in the thresholded image, the processor identifies the center C_1 of the circular outline 238.

After the processor 110 has identified the circular outline 238 and the center C_1 thereof for the pericentric view of the stack of gaming tokens 124 in the thresholded image, the processor 110 may perform the stack size estimation act 232, wherein the processor 110 may correlate the radius of the circular outline 238 with the radii of similar outlines of known stack sizes with variable amounts of tokens therein. For example, radii of outlines of stacks of gaming tokens with as few as one token therein and as many as fifteen (15) or more tokens therein may be stored in processor memory. The processor 110 may recall these radii when performing the stack size estimation act 232 and when estimating the number of tokens in the stack 124.

After the stack size estimation act 232 has been completed, the processor 110 may perform the layer identification act 234. Referring now to FIG. 25, a two-dimensional, pericentric, background-subtracted image of the lateral side surface 146 of the stack of gaming tokens 124 is depicted. It is to be appreciated that, in the two-dimensional, pericentric, background-subtracted image of the stack, the circular outline 238 of the stack represents, in three-dimensional space, an upper edge of the lateral side surface of the topmost gaming token in the stack. Furthermore, a radially outermost edge of a token in the stack, in the two-dimensional, pericentric image of FIG. 25, represents an upper edge of the token in three-dimensional space. Similarly, a radially innermost edge of a token in the stack depicted in FIG. 25 represents a lower edge of the token in three-dimensional space. During the layer identification act 234, the processor 110 may identify the outlines of the lateral side surfaces of each gaming token in the stack by performing an edge detection algorithm and correlating the detected edges with the previously estimated number of gaming tokens in the stack and the expected circle radius of the outermost and innermost edges of each token therein. The edge detection algorithm may include, by way of non-limiting example, a "difference of Gaussians" method, wherein the image, with the background subtracted, is converted to grayscale and a first blurred version of the image is subtracted from a second, less blurred version of the image. In this example, to acquire the first blurred version of the image, the grayscale image may be convolved with a first Gaussian kernel (3×3) having a first standard deviation. To acquire the second, less blurred version of the image, the grayscale image may be convolved with a second Gaussian kernel (7×7) having a standard deviation less than the standard deviation of the first Gaussian kernel. Subtracting the first blurred image from the second, less blurred image preserves spatial information lying between the range of frequencies preserved in the first and second blurred images, revealing edges or outlines present in the original image, as shown in the edge detection image of FIG. 26. As shown in FIG. 26, the edges present in the edge detection image may not be complete circles, but may be circular fragments.

After edge detection is performed, the processor 110 may correlate the estimated stack size, the estimated number of gaming tokens in the stack, the expected circle radii for each token therein, and the edges detected during the edge detection act to identify the radial inner and outer boundaries of each token in the stack 124. The radial area between the radially-outermost and -innermost boundaries of each token in the stack 124 may be termed a "layer" of the stack 124, wherein each layer represents the lateral side surface of the associated token. The processor 110 may identify boundaries of the layers of the stack working radially inward from the circular outline 238 to a radially-innermost boundary of the bottom token in the stack 124. Thus, the topmost token in the stack may be termed the "first token" 240*a*, the token in the second-from-the-top position in the stack may be termed the "second token" 240*b*, the token in the third-from-the-top position may be termed the "third token" 240*c*, and the underlying tokens may respectively be termed the "fourth token" 240*d*, the "fifth token" 240*e* and the "sixth token" 240*f*, respectively, with the sixth token 240*f* being the bottommost token in the stack 146 depicted in FIG. 26.

Similarly, the lateral side surface of the first token **240***a* may be termed a "first layer" L_1, the circumference of the lateral side surface of the second token **240***b* may be termed a "second layer" L_2, the circumference of the lateral side surface of the third token **240***c* may be termed a "third layer" L_3, the circumference of the lateral side surface of the fourth token **240***d* may be termed a "fourth layer" L_4, the circumference of the lateral side surface of the fifth token **240***e* may be termed a "fifth layer" L_5, and the circumference of the lateral side surface of the sixth token **240***f* may be termed a "sixth layer" L_6 of the stack **124**.

As shown in FIG. **26**, the radially innermost edge of a token and a radially outermost edge of the underlying token may together be depicted as a single edge (i.e., "boundary") between the adjacent tokens (i.e., "layers"). However, in other embodiments where tokens in the stack are misaligned (not shown), the radially innermost edge of a token may not coincide with a radially outermost edge of the underlying token. It is to be appreciated that the embodiments disclosed herein are capable of accommodating a degree of misalignment of the tokens in the stack **124**.

The processor **110** may determine the location of the boundaries of the layers L_1-L_6 by correlating the edges depicted in the edge detection image, the previously-estimated number of tokens in the stack and expected circle radius for each token therein, and subsequently using the correlated data to perform three-point circle fit functions on non-zero points within annular bands in the edge detection image corresponding to the expected circle radii previously determined by the processor **110**. The resulting circles formed by these circle fit functions may correspond to the boundaries of each of the layers L_1-L_6 in the stack **124**.

FIGS. **27** through **29** illustrate a non-limiting example of a method for identifying boundaries of the inner layers L_1-L_6 of the stack **124**. FIG. **27** illustrates a non-limiting example of an algorithm **500** for identifying inner layer boundaries. FIG. **28** illustrates an edge detection image of the stack of gaming tokens shown in FIG. **26** on which the algorithm **500** of FIG. **27** is performed. FIG. **29** illustrates a circle produced by the fit function of the algorithm **500** of FIG. **27**, wherein the circle represents a radially inner boundary of the first layer L_1.

Referring to FIG. **27**, after commencement of the inner boundary detection algorithm **500** at act **502**, the processor **110** may proceed to act **504** to find the outline of the pericentric view of the stack **124** in the thresholded image, as previously described with respect to the algorithm **400** of FIG. **25**, and utilize the radius of the circular outline **238** to estimate the size of the stack **124** and the number of tokens in the stack **124**. At act **506**, the processor **110** equivocates the present layer analyzed with the stack size, i.e., the circular outline **238** previously derived. At act **508**, the processor **110** utilizes the estimated stack size and estimated number of tokens in the stack **124** to determine whether the present layer represents a quantity of tokens in the stack greater than one (1). If the processor **110** determines that the present layer represents a position from the bottom of the stack **124** equal to or less than one (1), the processor **110** determines that the boundaries of each of the layers have been identified and terminates the algorithm at act **510**. However, if the processor **110** determines that the present layer represents a position from the bottom of the stack **124** greater than one (1), for example, if the present layer represents the topmost token in the stack **124**, the processor proceeds to act **512**, wherein the processor **110** recalls the location of the center C_1 of the circular outline **238** and uses the center C_1 as a starting point to determine, at act **514**, the boundaries of the immediately underlying layer, which become the present layer analyzed.

At act **516**, the processor **110** may utilize the estimated stack size and the estimated number of tokens in the stack to recall an expected circle radius for the present layer. At act **518**, the processor **110** may utilize image data in the edge detection image within an annular band surrounding the expected circle radius to identify non-zero points to utilize to perform a circle fit function. After the circle fit function is complete to identify a circle representing a boundary of the present layer, the processor **110** may identify and log a center of the circle at act **520** for use in act **512** on the following iteration. After act **520**, the processor may return to act **508** and repeat the process for the underlying layers until the present layer represents a position from the bottom of the stack equal to or less than one (1). In this manner, the processor **110** analyzes and identifies the layers L1-L6 working radially inward from the outer boundary **238** of the outer token **240***a* in the pericentric image.

Referring now to FIGS. **28** and **29**, a visual representation of an embodiment of the algorithm **500** of FIG. **27** is illustrated. For example, to determine the bounds of the first layer L_1, after previously determining the circular outline **238** and the center C_1 thereof, the processor **110** may identify, in the edge detection image, non-zero points P_1, P_2, P_3, P_4 within four (4) quadrants Q_1-Q_4 and within an annular band **242** corresponding to the expected circle radius for the radially-innermost edge of the first token **240***a*, wherein the expected circle radius is measured from the center C_1 of the circular outline **238**. The processor **110** may adjust the radial width of the annular band **242** as necessary to accommodate varying degrees of token misalignment in the stack **124**. As shown in FIG. **29**, the processor **110** may then use the three non-zero points with the greatest angular distance therebetween P_1, P_2, P_3 to perforin a circle fit function to form a circular outline **244** representing the inner boundary of the first layer L_1, wherein the circular outline **238** of the stack **124** and the circular outline **244** of the radially-innermost edge of the first token **240***a* together mark the boundaries of the first layer L_1. The processor **110** may also log the center C_2 of the circular outline **244** of the inner edge of the first token **240***a* for use with locating the expected circle radius of the next inner boundary. The successive boundaries of the inner layers L_2-L_6 and their corresponding centers may be determined in a similar manner. It is to be appreciated that the center of each boundary may be logged and used by the processor **110**, in connection with the expected circle size for each layer, to determine the annular band within which to identify non-zero points and perform a circle fit function for the succeeding inner boundary. The process may be repeated until the boundaries of each layer are identified.

Referring now to FIG. **30**, after the centers and boundaries of the layers L_1-L_6 are determined for the tokens in the pericentric image of the lateral side surface **146** of the stack of gaming tokens **124**, the processor **110** may perform the cylindrical projection act **236** to convert the layers L_1-L_6 from a pericentric orientation to a linear orientation of a cylindrical projection, as previously described herein. Because the centers for each of the tokens, such as centers C_0 and C_1 shown in FIG. **29**, may not by aligned, the processor **110** may convert each layer from a pericentric orientation into a linear orientation separately. The cylindrical projection act may complete the preprocessing stage **224** of the token pattern detection algorithm **220**.

Referring now to FIG. **31**, an algorithm of the detection stage **226** is shown. In the detection stage **226**, the processor **110** may perform a color content analysis **246**, a pattern

correlation act **248**, a pattern subtraction act **250**, a pattern score calculation **252**, and a detection output result act **254** on each layer L_1-L_6 in the linear projection image, as set forth more fully below.

In the color content analysis act **246**, color content histograms may be derived for each layer previously linearly projected. For example, at least one line having a plurality of reference points may be projected horizontally through each liner layer. The processor **110** may then perform an algorithm to identify the color intensity at each reference point on each line extending horizontally through each layer for each of the red, green and blue colors on a red blue green (RGB) color scale. After the processor **110** has identified the color intensity for each color on the RGB scale at each reference point on the line, a reference graph, such as a histogram, may be plotted and stored in the processor memory charting the color intensity for each color on the RGB scale at each reference point on the line. The processor **110** may compare the histogram for each layer to histograms of template match candidates stored in memory to preselect a limited amount of template match candidates to which each linear layer will be compared in the pattern correlation act **248**.

In the pattern correlation act **248**, the processor **110** may compare patterns within each linear layer to patterns of the template match candidates identified by the processor **110** in the color content analysis act **246**. The processor **110** may select a limited region, or "patch" **256**, of each layer, as shown in FIG. **30**, for further correlation with the template match candidates preselected by the processor **110**. The layer patch **256** may have a horizontal length equivalent to an arc length of the lateral side surface of the token subtending an angle between about 100 degrees and about 260 degrees in three-dimensional space. In other embodiments, the layer patch **256** may have a horizontal length equivalent to an arc length of the lateral side surface of the token subtending an angle between about 120 degrees and about 220 degrees in three-dimensional space. In further embodiments, the layer patch **256** may have a horizontal length equivalent to an arc length of the lateral side surface of the token subtending an angle between about 140 degrees and about 180 degrees in three-dimensional space. In yet additional embodiments, the layer patch **256** may have a horizontal length equivalent to an arc length of the lateral side surface of the token subtending an angle of about 160 degrees in three-dimensional space from a center of the token. It is to be appreciated that the size of the layer patch **256** may depend on patterns in the linear layer and may be predetermined for particular token types and sizes. After the layer patch **256** is defined, the processor **110** may compare the patterns within the layer patch **256** to patterns within each of the template match candidates preselected during the color content analysis **246** to determine the relative positions of the layer patch **256** and each template match candidate at which the layer patch **256** correlates most closely with the patterns in the template match candidate. The position of closest correlation may be determined using a template matching function. By way of non-limiting example, the template matching function may effectively slide the layer patch **256** over an image of each template match candidate pixel by pixel and compare the overlapping layer patch **256** and template match candidate using a normalized squared difference function, such as the following function,

$$R(x, y) = \frac{\sum_{x',y'} (T(x', y') - I(x + x', y + y'))^2}{\sqrt{\sum_{x',y'} T(x', y')^2 \cdot \sum_{x',y'} I(x + x', y + y')^2}},$$

to compile a result matrix R indicating how closely the layer patch **256** "matches" the template match candidate at each (x, y) coordinate of the template match candidate. In this normalized squared difference function, R represents the result, T represents the layer patch **256**, I represents the pattern match candidate, x and y represent Cartesian coordinates of the template match candidate, and x' and y' are variables associated with the width and height of the layer patch **256**, as defined in The OpenCV Reference Manual at pp. 337-38 (Release 2.4.9.0, Apr. 21, 2014), the entire disclosure of which is incorporated herein by this reference, available at: http://docs.opencv.org/modules/imgproc/doc/object_detection.html?highlight=matchtemplate#matchtemplate (last referenced Sep. 18, 2014). Lower result values R returned from the normalized squared difference function indicate better matches between the layer patch **256** and the template match candidate. The result matrix R from the normalized squared difference function allows the processor **110** to identify the location within each template match candidate at which the layer patch **256** most closely matches the template match candidate and to calculate an associated pattern correlation value, or score, for each template match candidate. The processor **110** may effectively freeze the layer patch **256** at the location of the template match candidate with the lowest pattern correlation value (highest degree of correlation) determined by the normalized squared difference function. The processor **110** may define a template patch (not shown) coextensive with the layer patch **256** at the location of the highest correlation therebetween as determined by the normalized squared difference function.

Then, in the pattern subtraction act **250**, the processor **110** may subtract the layer patch **256** from the template patch and threshold an image of the template patch. The processor **110** may then compare the pixels of the layer patch **256** with the pixels of the thresholded template patch. The processor **110** may determine a pixel correlation value by counting the amount of pixels in the layer patch **256** exciding the threshold of the template patch to determine a number of pixels in the layer patch **256** that are different from those of the template patch, wherein a pixel correlation score of 0 indicates a perfect match between the layer patch **256** and the template patch.

In the pattern score calculation act **252**, the processor **110** may utilize both the pattern correlation value and the pixel correlation value to calculate a final correlation score between the layer patch **256** and each of the template match candidates. A user may set a predetermined threshold score below which the final correlation score must rate to be considered a "pattern match." If the final correlation score is below the threshold score, the processor **110** may indicate a "pattern match" status for the template match candidate. If the final correlation score is above the threshold value, the processor **110** may indicate only the presence of a token in the analyzed layer. The processor **110** may calculate and log the final correlation scores for each of the template match candidates preselected during the color content analysis act **246**. In the detection output result act **254**, the processor **110** may assign the template match candidate with pattern match status having the most favorable final correlation score a

"final match" status. The processor **110** may then assign the layer the wager value associate with the template match candidate having final match status. The acts of the detection stage **226** may be repeated for each layer in the linear projections of the lateral side surfaces of the stack of gaming tokens. The processor **110** may add the wager values for each layer to calculate the sum wager value for the stack of gaming tokens **124**.

It is to be appreciated that the template match candidates stored in processor memory may include template match candidates derived from images of tokens not centered on the bet placement surface **122**. In this manner, if one of the linear layers of the stack **124** is associated with a misaligned token, the processor **110** may have template match candidates of misaligned tokens from which to select when performing the color content analysis **246**. Furthermore, to accommodate circumstances where the illumination saturation level of the lateral side surface of each token varies according to the vertical location of the token within the stack **124**, the template match candidates may be derived from images of tokens located at various vertical locations within the stack **124** to provide template match candidates for each reference token at varying illumination saturation levels.

The processor **110** may possess the computing power to perform the necessary computations to determine the value of the stack of gaming tokens **124** in about ten (10) seconds or less. In some embodiments, the processor **110** may possess the computing power to perform the necessary computations to determine the value of the stack of gaming tokens **124** in about one (1) second or less. In further embodiments, the processor may possess the computing power to perform the necessary computations to determine the value of the stack of gaming tokens **124** in about 0.5 second or less. In yet further embodiments, the processor may possess the computing power to perform the necessary computations to determine the value of the stack of gaming tokens **124** in about 0.1 second or less. The processor **110** may be capable of supporting software development tools and providing ease of integration with the image sensor **106**. For example, the processor **110** may be what is referred to in the art as an "ARM" based processor, such as, by way of non-limiting example, an open multimedia applications platform (OMAP) processor produced by Texas Instruments of Dallas, Tex., a Sitara microprocessor produced by Texas Instruments, or a S3C6410 model mobile processor produced by Samsung of Seoul, Korea. However, it is to be appreciated that any processor or combination of processors capable of performing the token recognition functions described above is within the scope of the embodiments disclosed herein.

As previously described with reference to FIG. **1**, the processor **110** may be in electronic communication with the display device **112** for displaying the wager value to a player and/or operator of a wagering game. The display device **112** may be a liquid crystal display (LCD), such as a 1 line by 8 character (1×8) LCD or a 2 line by 8 character (2×8) LCD, either of which may optionally include a backlight. Alternatively, the display device **112** may include LEDs, organic LEDs (OLEDs), AMOLEDs, thin-film transistors (TFTs), a graphic LCD, or any combination thereof. In yet other embodiments, the display device **112** may comprise transparent LCD digital signage. As used herein, the term "transparent LCD digital signage" means and refers to a device comprising an LCD display embedded within a transparent or semi-transparent material. For example, in such embodiments, the transparent cover **102**, or a portion thereof, may be integrated with an LCD display to form the display device **112** having transparent LCD digital signage, wherein the LCD display is configured to project static images, dynamic images, or any combination thereof on a surface of the transparent cover **102** that is visible by a player. In other words, the display device **112** may comprise at least a portion of the transparent cover **102**, wherein the at least a portion of the transparent cover **102** is configured to display information visible to the player. For example, such information may include the wager value of the stack of gaming tokens **124**. In such embodiments, the transparent cover **102** may be transparent or semi-transparent to visible light. The display device **112** configured to include transparent LCD digital signage may be in electronic communication with the processor **110**, as previously described, wherein the images displayed on the display device are controlled by the processor **110**. By way of a non-limiting example, the display device **112** configured to include transparent LCD digital signage may be a STA1713 model transparent LCD digital signage, produced by LiteMax Electronics, Inc. of New Taipei, Taiwan. It is to be appreciated that any device for displaying the wager value to a player and/or operator of the game is within the scope of the embodiments disclosed herein.

The bet sensor **100** may also be capable of communicating other information to a player of the game. For example, in addition to illuminating the stack of gaming tokens **124**, the LEDs **107** may also be utilized as an indicator light system to communicate information to a player and/or operator of the game responsive to a state of the game. For example, a casino may wish to limit the duration during which a player may place a wager or indicate a player who has won a game. In some embodiments, the bet sensor **100**, including the LEDs **107**, the first reflective structure **130**, and the transparent cover **102**, may be configured to provide indicator light signals to a player of the game. In some embodiments, additional LEDs **107** of varying light color emissions may be used to, for example, signal an approached end of a period for wager placement, to indicate the end of such period, to indicate a winner of a round of a game, or all of the foregoing. In other embodiments, LEDs **107** may be strobed in different patterns to indicate one or more of the foregoing game-associated events. In any such embodiments, the bet sensor **100** may include at least one optical element that is configured to transmit visible light emitted by the LEDs **107** or another indicator light to a player and/or operator of the game.

For example, a light guide element **156** optionally may be located on an underside of the transparent cover **102**, as illustrated in FIG. **16**. The light guide element **156** may have an annular configuration and may be concentrically aligned with the hub structure **134**. The light guide element **156** may comprise a portion of the transparent cover **102** or may comprise a separate structure affixed to the transparent cover **102**. In embodiments in which the light guide element **156** is a separate structure attached to the transparent cover **102**, the attachment of the light guide element **156** to the transparent cover **102** may be accomplished by a mechanical fastener, an adhesive, or other means of attachment. The light guide element **156** may be configured to channel light emitted from the LEDs **107** and transmit the channeled light in an even dispersion through a portion of the transparent cover **102** adjacent the light guide element **156**. A portion of the top surface of the transparent cover **102** positioned above the light guide element **156** may comprise an optical surface element **158** configured to increase visibility of the light transmitted through the light guide element **156**. The optical

surface element **158** may comprise a textured or "frosted" diffuser portion of the top surface of the transparent cover **102** and may be configured to transmit an even dispersion of light in a ring configuration corresponding to the light guide element **156**. The frosted diffuser portion **158** of the transparent cover **102** may be formed by an etching process, including, by way of non-limiting example, a mechanical etching process, a chemical etching process, a laser etching process, a grinding process, or other processes known in the art. Thus, the processor **110** may control the LEDs **107** to emit light in cooperation with the light guide element **156**, the transparent cover **102**, and the optical surface element **158** to provide lighting effect signals for communicating information to a player. For example, when the bet sensor is in a mode to attract players, the processor **110** may control the LEDs **107** to cause the optical surface element **156** to blink in a uniform manner. When the bet sensor is in a mode to indicate a live betting, the processor **110** may control the LEDs **107** to cause the optical surface element **156** to transmit a solid ring of color. When the bet sensor is in a payout mode, the processor **110** may control the LEDs **107** to cause the optical surface element **156** to transmit lights effectively running around the circumference of the optical surface element **156**, also known as "chase lights." As noted above, the lighting signals may include emission of different colors of light to represent different signals. For example, a green light may indicate that a wager may be placed, while a red light may indicate that a wager may not be placed.

In embodiments in which the display device **112** comprises the transparent cover **102** configured with transparent LCD digital signage, the display device **112** may also be used as an indicator light system similar to that previously described. In such embodiments, the display device **112** may be controlled by the processor **110** to communicate information to a player responsive to a state of the game. In addition to displaying a wager value to a player, the display device **112** configured with transparent LCD digital signage may be configured to display, by way of non-limiting example, a dynamic countdown encouraging a player to place a wager within a predetermined time, an indication of the status of the game being played, a dynamic or static image indicating which game is being played, advertisements, or any other information a gaming institution wishes to communicate to a player.

FIG. **17** illustrates a non-limiting example of a circuit that may be used in the LED driver **116** of FIG. **1**. As shown in FIG. **1**, the LED driver **116** may comprise a drive circuit **162** that may be used to allow the processor **110** to control the LEDs **107** for both illuminating the stack of gaming tokens **124** and for providing indicator lighting effects to a player. The drive circuit **162** may comprise a pulse-width modulation (PWM) multiplexed circuit including a microcontroller **164**, such as what is referred to in the art as a "PIC" microcontroller, configured to transform a command signal from the processor **110** into a plurality of command signals. The plurality of command signals may include at least one unique command signal for each LED **107** of the plurality of LEDs. The drive circuit **162** is illustrated as having a set of nine (9) LEDs **107***a*-**107***i* connected thereto; however, it is to be understood that any number of LEDs may be connected to the drive circuit **162**, including each LED **107** of the illumination unit **120**. A multiplexer **166** may be electronically interposed between the microcontroller and each of the LEDs **107**, and may direct each individual command signal from the microcontroller **164** to a specific LED **107**. In this manner, the function of each LED **107** may be controlled by the processor, including color, intensity, fading, and strobe or pulse effects, to create a desired overall lighting effect for illuminating the stack of gaming tokens **124** or communicating information to a player.

As previously described with reference to FIG. **1**, the processor **110** may be in electronic communication with a table controller **114**. For example, a wire or cable may extend from the processor **110** (or the image sensor module **148**) to the table controller **114**, such as an Ethernet or USB cable. Alternatively, the table controller **114** may communicate wirelessly with the processor **110**. The table controller **114** may be a PC-based computer platform with a display screen for displaying the wager value transmitted from the processor **110** to a table operator. The table controller **114** may include a user interface configured to allow the table operator to accept, reject, or correct the wager value. The table controller **114** may comprise an override function allowing the table operator to input a corrected wager value, wherein the corrected wager value may be transmitted from the table controller **114** to the processor **110** and subsequently displayed by the display device **112**. The table controller **114** may also be configured to allow the table operator to communicate various signals to a player of the game through the indicator light system described above. For example, the table operator may select a signal command output from a list of signal command outputs stored in the table controller **114**. The table controller **114** may subsequently transmit the signal command to the processor **110**. The processor **110** may then transmit the signal command to the LED driver **116**, wherein the LED driver **116** may process the signal command to control the LEDs **107**, as previously described.

In some embodiments, the bet sensor **100** may comprise a modular configuration for ease of assembly. For example, as described above, the transparent cover **102**, the first reflective structure **130**, and the hub structure **134** may each be removably coupled together to provide simple assembly and disassembly of the illumination unit **120**. Additionally, the optional lens **104** may be removably coupled to the image sensor **106**. The image sensor **106** may be removably coupled with the processor **110**, and the processor **110** may be removably coupled with the table controller **114**. Theremovable attachment of these components may allow for ease of assembly and interchangeability of these components. Bet sensors **100** of the present invention may be connected in series to a processor as described in co-pending U.S. patent application Ser. No. 12/946,814, filed Nov. 5, 2010, entitled "Wager Recognition System," the disclosure of which is incorporated herein in its entirety by this reference.

FIG. **18** illustrates an embodiment of a gaming table **168** of the present disclosure, which includes a table having an upper playing surface **170** and a plurality of apertures, each of which apertures extends through the upper surface of the table proximate each of a plurality of corresponding player positions **172***a*-**172***g* at the table. The gaming table **168** further includes bet sensors **100** as described herein mounted to the table proximate, or, in some embodiments, within, the apertures extending through the upper surface of the table. For example, each bet sensor **100** may be mounted to the table **168** such that the transparent cover **102** is disposed in and covers the associated aperture. The upper betting surface **122** of the transparent cover **102** may be at least substantially flush with the upper playing surface **170** of the table **168**.

A table controller **114** may be operatively coupled to the plurality of bet sensors **100**. Each player position **172***a*-**172***g* may include a bet sensor **100***a*-**100***g* and a display device **112***a*-**112***g*, each of which may be configured as previously

described herein. The processor **110** (not shown in FIG. **18**) of each bet sensor **100***a*-**100***g* may be in electronic communication with the table controller **114**, as previously described. The table **168** may further include additional features, such as a dealer chip tray **174**, which may be used by the dealer to cash players in and out of the wagering game. For embodiments using physical cards **176***a*, **176***b*, the table **168** may further include a card handling device **178** that may be configured to shuffle, read, and deliver physical cards for the dealer and players to use during game play or, alternatively, a card shoe configured to read and deliver cards that have already been randomized. For embodiments using virtual cards, such virtual cards may be displayed on a display screen (not shown) at each of the individual player positions **172***a*-**172***g*. Common virtual cards may be displayed in a common card area (not shown). The table controller **114** may further include an interface **180**, which may include touch screen controls for assisting the dealer in administering the wagering game. The table **168** may further include an upright display **182** configured to display images that depict game information such as pay tables, hand counts, historical win/loss information by player, and a wide variety of other information considered useful to the players. The upright display **182** may be double sided to provide such information to players as well as to a casino pit. It is to be appreciated that the bet sensors **100***a*-**100***g* may have a modular configuration to provide ease of integration with the gaming table **168**.

In other embodiments, at least a majority of the image processing and computations may be performed by the table controller instead of by each individual bet sensor. Referring now to FIG. **19**, a simplified schematic diagram of another embodiment of a bet sensor **200** is illustrated. The bet sensor **200** may be generally configured as described previously in reference to FIG. **1**, and may include a transparent cover **202** in visual register with a lens **204**. The transparent cover **202** may be embedded in a gaming table and may be configured to receive a stack of gaming tokens thereon. An image sensor **206** may be positioned to view the stack of gaming tokens through the transparent cover **202** and the lens **204**. Proximate the transparent cover **202** may be located one or more light-emitting diodes (LEDs) **207** configured for illuminating the stack of gaming tokens to provide a satisfactory image of the stack viewable by the image sensor **206**. Each of the LEDs **207** may be configured with a lens **208** to provide desired light emission qualities. The image sensor **206** may be in electronic communication with a field programmable gated array (FPGA) **209** configured to capture images from the image sensor **206** and transmit the images to a processor **210** located in a table controller **211**. In alternative embodiments, any image processor may be utilized in place of the FPGA **209**.

As previously described, the table controller **211** may be a personal computer (PC) based computing platform, and, in the embodiment illustrated in FIG. **19**, the processor **210** may be located on the table controller **211**. The processor **210** may be configured to receive a stream of captured images of the stack of gaming tokens from the FPGA **209** and to process the images (i.e., perform one or more algorithms using the images) to calculate the values of the stack of chips depicted therein. The processing algorithms performed by the processor **210** to determine the wager values may be performed as previously described herein. After the processor **210** has determined a wager value of a stack of gaming tokens, the processor **210** may display the wager value on a screen of a user interface of the table controller **211**. The user interface may be configured to allow a table operator to accept, reject, or correct the wager value. The table controller **211** may comprise an override function allowing the table operator to input a corrected wager value. The processor **210** may be configured to transmit a display signal comprising the wager value to the FGPA **209**. After receiving the display signal from the processor **210**, the FGPA **209** may transmit the display signal to a display device **212**. The display device **212** may be configured to display the wager value to the player who placed the wager, to other players, to a table operator, or to any combination thereof. The display device **212** may be configured as previously described herein.

An LED driver **216** may be electronically interposed between the FGPA **209** and the LEDs **207**. As previously described herein, the processor **210** may be configured to control the lighting effects of the LEDs **207** for illuminating the stack of gaming tokens and for communicating information to players. To control the LEDs **207**, the processor **210** may transmit lighting command signals to the FPGA **209**, which may transmit the lighting command signals to the LED driver **216**. The LED driver **216** may be configured as previously described herein, and may process the lighting command signals as previously described. The FPGA **209** and at least the LED driver **216** may be located on a printed circuit board (PCB) **218**, and electronic communication between the FPGA **209** and the LED driver **216** may be provided through conductive traces, vias and interconnects in the PCB **218**, as is known in the art.

Additionally, the table controller **211** may be configured to enable the table operator to communicate various signals to a player of the game through the indicator light system described above. As previously described, the computer program and/or table operator may select a lighting command signal output from a list of lighting commands stored in the table controller **114**. Furthermore, the table controller **211** may be integrated with a plurality of bet sensors **200** embedded in a gaming table, wherein the table controller **211**, including the processor **210**, may be configured to operate each bet sensor **200** of the plurality of bet sensors **200**. In some embodiments, the table controller **211** may be integrated with up to seven (7) bet sensors **200** embedded in a gaming table. It is to be appreciated that any number of bet sensors **200**, including more than seven (7), may be integrated with the table controller **211**.

Referring now to FIG. **20**, an embodiment of an another suitable location for the LEDs is illustrated. An illumination unit **300** may be generally configured as described above with reference to FIGS. **2** through **6**, including a transparent cover **302** having a bet placement surface **304** for supporting a stack of gaming tokens **306** thereon. The cover glass may define an annular recess **308** on an underside of the transparent cover **302**. One or more LEDs **310** may be positioned on a PCB **312**, wherein at least part of the LED **310** is located within the annular recess **308**. The LEDs **310** may be of any of the types previously described, and each may be configured to emit light through an LED lens **314** and toward the stack of gaming tokens **304**. The transparent cover **302** may be configured to internally reflect a majority of the light rays emitted by the LEDs **310**. A bottom surface of the transparent cover **302** may define a frustoconical portion **316** adjacent a conformal reflective surface **318** configured to eject internally reflected light rays out of the transparent cover **302** and onto the stack of gaming tokens **306**.

Additionally, the transparent cover **302** and LEDs **310** may be configured to provide indicator light signals to a player of the game, as previously described. A light guide element **320** may be located in the annular recess **308** above

the one or more LEDs **310** and on an underside of the transparent cover **302**. The light guide element **320** may have a continuous annular configuration. The light guide element **320** may be configured to collect light emitted from the LEDs **310** and transmit the collected light in an even dispersion through a portion of the transparent cover **302** corresponding to the light guide element **320**. Additionally, a portion of the top surface of the transparent cover **302** positioned above the light guide element **320** may comprise a surface element **322** configured to increase visibility of the light transmitted through the light guide element **320** and the transparent cover **302**. The surface element **322** may comprise a textured, or "frosted," diffuser portion of the top surface of the cover glass. The textured diffuser portion may be configured to transmit an evenly-dispersed ring of light to a player. As previously described, the LEDs **310** may be controlled by the processor **110** to emit light in cooperation with the light guide element **320**, the transparent cover **302**, and the surface element **322** to provide multicolored lighting effect signals for communicating information to a player.

The embodiments of the disclosure described above do not limit the scope of the disclosure, which is defined by the scope of the appended claims and their legal equivalents. Any equivalent embodiments are within the scope of this disclosure. Indeed, various modifications of the disclosure, in addition to those shown and described herein, such as alternate useful combinations of the elements described, will become apparent to those of ordinary skill in the art from the description. Such modifications and embodiments also fall within the scope of the appended claims.

What is claimed is:

1. A bet sensor for sensing values of multiple gaming tokens, comprising:

a bet placement surface configured and oriented to support a stack of gaming tokens thereon;

an image sensor located and oriented to capture an image of a lateral side surface of at least one gaming token located on the bet placement surface, wherein the image depicting the lateral side surface is in a radial format depicting the lateral side surface of the at least one gaming token about a majority of a circumference of the at least one gaming token; and

a processor in communication with the image sensor, the processor configured to acquire image data from the image and analyze the image data to determine a wager value of the at least one token; and

memory associated with the processor, the memory containing a plurality of template match candidates, each of the plurality of template match candidates comprising a depiction of at least a portion of a lateral side surface of an associated template gaming token, each associated template gaming token having an associated wager value stored in the processor memory.

2. The bet sensor of claim **1**, wherein the processor outputs a signal to a display device configured to receive information associated with the wager value from the processor and display the wager value.

3. The bet sensor of claim **1**, wherein:

the at least one gaming token comprises a plurality of gaming tokens arranged in a stack located on the bet placement surface, and the processor is configured to convert the image into a plurality of converted images, each of the plurality of converted images depicting, in the form of a linear layer, a lateral side surface of an associated gaming token of the plurality of gaming tokens in the stack of gaming tokens; and each of the plurality of template match candidates further comprises a linear depiction of the at least a portion of the lateral side surface of an associated template gaming token.

4. The bet sensor of claim **1**, wherein the processor is configured to analyze the image data and categorize the image data with a unique image content signature derived from the image data.

5. The bet sensor of claim **4**, wherein the image data comprises color data, and the unique image content signature comprises a color content histogram of the image.

6. The bet sensor of claim **5**, wherein the memory contains color content histograms of substantially each of the plurality of template match candidates.

7. The bet sensor of claim **6**, wherein the processor is configured to automatically compare the color content histogram of the image with the color content histograms of substantially each of the plurality of template match candidates stored in the memory and identify a sub-group of the plurality of template match candidates having a predetermined degree of similarity with the color content of the image for further comparison with the image.

8. The bet sensor of claim **7**, wherein the processor is configured to compare a portion of the image with each of the sub-group of the plurality of template match candidates.

9. The bet sensor of claim **8**, wherein the processor is configured to compare patterns within the portion of the image with patterns within each of the sub-group of the plurality of template match candidates using a normalized squared difference function, wherein the normalized squared difference function returns a pattern correlation value identifying a degree of similarity between the portion of the image and each of the sub-group of the plurality of template match candidates.

10. The bet sensor of claim **1**, further comprising a media controller in communication with the image sensor, the media controller operated by the processor, the media controller outputting the image to the processor in a predetermined format.

11. The bet sensor of claim **10**, further comprising an illumination system located and oriented to illuminate the lateral side surface of the at least one gaming token, wherein the processor is configured to cause the media controller to discard images of the lateral side surface of the at least one gaming token not illuminated by the illumination system.

12. A bet sensor for sensing values of multiple gaming tokens, comprising:

a bet placement surface configured and oriented to support a stack of gaming tokens thereon;

an image sensor located and oriented to capture an image of a lateral side surface of at least one gaming token located on the bet placement surface, wherein the image depicting the lateral side surface is in a radial format depicting the lateral side surface of the at least one gaming token about a majority of a circumference of the at least one gaming token;

a processor in communication with the image sensor, the processor configured to acquire image data from the image and analyze the image data to determine a wager value of the at least one token; and

memory associated with the processor, the memory containing a plurality of template match candidates, the memory containing color content histograms of substantially each of the plurality of template match candidates, each of the plurality of template match candidates comprising a depiction of at least a portion of a lateral side surface of an associated template gaming

token, each associated template gaming token having an associated wager value stored in the processor memory;

wherein:

the processor is configured to analyze the image data comprising color data and categorize the image data with a unique image content signature comprising a color content histogram of the image derived from the image data;

the processor is configured to automatically compare the color content histogram of the image with the color content histograms of substantially each of the plurality of template match candidates stored in the memory and identify a sub-group of the plurality of template match candidates having a predetermined degree of similarity with the color content of the image for further comparison with the image;

the processor is configured to compare a portion of the image with each of the sub-group of the plurality of template match candidates;

the processor is configured to compare patterns within the portion of the image with patterns within each of the sub-group of the plurality of template match candidates using a normalized squared difference function, the normalized squared difference function configured to return a pattern correlation value identifying a degree of similarity between the portion of the image and each of the sub-group of the plurality of template match candidates;

the processor is configured to match the portion of the image with an equivalently-sized portion of each of the sub-group of the plurality of template match candidates at a location of each of the sub-group of the plurality of template match candidates returning an optimal pattern correlation value; and

the processor is further configured to identify each pixel of the portion of the converted image that is excised from an associated location of the equivalently-sized portion of each of the sub-group of template match candidates and calculate a pixel correlation value for each of the sub-group of the plurality of template match candidates.

13. The bet sensor of claim **12**, wherein the processor is configured to calculate from the pattern correlation value and the pixel correlation value for each of the sub-group of the plurality of template match candidates a final correlation score for each of the sub-group of the plurality of template match candidates.

14. A gaming table, comprising:

at least one bet sensor located proximate a surface of the gaming table, the at least one bet sensor comprising the bet sensor of claim **1**.

15. The gaming table of claim **14**, wherein the processor outputs a signal to a display device configured to receive information associated with the wager value from the processor and display a total wager value to a player of a game played at the gaming table, wherein the total wager value includes the wager value of the at least one gaming token.

16. The gaming table of claim **15**, further comprising memory associated with the processor, the memory containing a plurality of template match candidates, each of the plurality of template match candidates comprising a depiction of at least a portion of a lateral side surface of an associated template gaming token, each of the plurality of template match candidates having an associated wager value stored in the processor memory.

17. The gaming table of claim **16**, wherein:

the processor is configured to convert the image into a form of a linear layer; and each of the plurality of template match candidates further comprises a linear depiction of the at least a portion of the lateral side surface of the associated template gaming token.

18. The gaming table of claim **17**, wherein the processor is configured to automatically compare color data of the linear layer with color data of substantially each of the plurality of template match candidates and identify a sub-group of the plurality of template match candidates having color data within a predetermined degree of similarity with the color data of the linear layer.

19. A gaming table, comprising:

at least one bet sensor located proximate a surface of the gaming table, the at least one bet sensor including:

a bet placement surface configured and oriented to support a stack of gaming tokens thereon;

an image sensor located and oriented to capture an image of a lateral side surface of at least one gaming token located on the bet placement surface, the image depicting the lateral side surface in a radial format;

a processor in communication with the image sensor, the processor configured to acquire image data from the image and interpret the image data to determine a wager value of the at least one gaming token; and

memory associated with the processor, the memory containing a plurality of template match candidates, each of the plurality of template match candidates comprising a depiction of at least a portion of a lateral side surface of an associated template gaming token, each of the plurality of template match candidates having an associated wager value stored in the processor memory and further comprising a linear depiction of the at least a portion of the lateral side surface of the associated template gaming token;

wherein:

the processor is configured to convert the image into a form of a linear layer;

the processor is configured to automatically compare color data of the linear layer with color data of substantially each of the plurality of template match candidates and identify a sub-group of the plurality of template match candidates having color data within a predetermined degree of similarity with the color data of the linear layer;

the processor is configured to compare patterns within a portion of the linear layer with patterns within each of the sub-group of the plurality of template match candidates; and

the processor returns a pattern correlation value identifying a degree of similarity between the portion of the linear layer and each of the template match candidates within the sub-group.

20. The gaming table of claim **19**, wherein the processor is configured to match the portion of the linear layer with an equivalently-sized portion each of the template match candidates within the sub-group at a location returning an optimal pattern correlation value, wherein the processor is further configured to identify each pixel of the portion of the linear layer that is excised from an associated location of the equivalently-sized portion of each of the template match candidates within the sub-group and calculate a pixel correlation value for each of the template match candidates within the sub-group.

21. The gaming table of claim **20**, wherein the processor is configured to calculate from the pattern correlation value

and the pixel correlation value a final correlation score for each of the template match candidates within the sub-group, wherein the processor is further configured to identify an optimal template match candidate of the sub-group having an optimal final correlation score and assign the linear layer a wager value associated with the optimal template match candidate.

22. A method of operating a gaming table having at least one bet placement surface thereon for supporting a stack of gaming tokens at a location, the method comprising: capturing, with an image sensor, an image of a lateral side surface of at least one gaming token at the location, wherein the lateral side surface is depicted in a radial format showing the lateral side surface of the at least one gaming token about a majority of an outermost lateral boundary of the at least one gaming token;

converting the image, with a processor, into a converted image depicting the lateral side surface of the at least one gaming token in a form of a linear layer; and

acquiring image data from the linear layer of the converted image with the processor;

analyzing the image data to determine a wager value of the at least one token.

23. The method of claim **22**, further comprising displaying the wager value on a display device associated with the gaming table.

24. The method of claim **23**, wherein analyzing the image data to determine a wager value of the at least one gaming token comprises:

comparing the image data from the linear layer with image data from a plurality of template match candidates stored in memory associated with the processor, wherein each of the plurality of template match candidates is associated with a wager value;

identifying an optimal template match candidate of the plurality of template match candidates having image data most similar to the image data from the linear layer; and

associating a wager value of the optimal template match candidate with the at least one token.

25. The method of claim **24**, wherein acquiring image data from the linear layer comprises:

deriving a color content histogram for the linear layer with the processor; and

comparing the color content histogram of the linear layer with color content histograms of the plurality of template match candidates.

26. The method of claim **25**, further comprising preselecting, with the processor, a sub-group of the plurality of template match candidates for further comparison with the linear layer, wherein each of the sub-group of the plurality of template match candidates having a color content histogram within a predetermined degree of similarity with the color content histogram of the linear layer.

27. The method of claim **22**, wherein converting the image, with a processor, into a converted image depicting the lateral side surface of the at least one gaming token in a form of a linear layer comprises:

removing background elements from the image prior to converting the image to form a background-subtracted image; and

identifying, in the background-subtracted image, boundaries of the at least one gaming token.

28. The method of claim **22**, wherein converting the image, with a processor, into a converted image depicting the lateral side surface of the at least one gaming token in a form of a linear layer comprises:

performing an edge detection algorithm on the image to produce an edge detection image;

analyzing image data in the edge detection image with the processor; and

correlating, with the processor, image data in the edge detection image with known token data stored in memory associated with the processor to identify radially inner and outer boundaries of the lateral side surface of the at least one gaming token in the image.

29. A method of operating a gaming table having at least one bet placement surface thereon for supporting a stack of gaming tokens at a location, the method comprising: capturing, with an image sensor, an image of a lateral side surface of at least one gaming token at the location, wherein the lateral side surface is depicted in a radial format;

converting the image, with a processor, into a converted image depicting the lateral side surface of the at least one gaming token in a form of a linear layer;

acquiring image data from the linear layer of the converted image with the processor, the acquiring comprising:

deriving a color content histogram for the linear layer with the processor; and

comparing the color content histogram of the linear layer with color content histograms of the plurality of template match candidates;

preselecting, with the processor, a sub-group of the plurality of template match candidates for further comparison with the linear layer, wherein each of the sub-group of the plurality of template match candidates having a color content histogram within a predetermined degree of similarity with the color content histogram of the linear layer; selecting, with the processor, a region of the linear layer for comparison with each of the sub-group of the plurality of template match candidates, wherein the region of the linear layer is less than a total area of the linear layer; and

analyzing the image data to determine a wager value of the at least one token, the analyzing comprising:

comparing the image data from the linear layer with image data from a plurality of template match candidates stored in memory associated with the processor, wherein each of the plurality of template match candidates is associated with a wager value;

identifying an optimal template match candidate of the plurality of template match candidates having image data most similar to the image data from the linear layer; and

associating a wager value of the optimal template match candidate with the at least one token.

30. The method of claim **29**, wherein the region of the linear layer has a horizontal length equivalent to an associated arc segment of a lateral side surface of a token depicted in the linear layer, wherein the associated arc segment subtends an angle between about 140 degrees and about 180 degrees from a center of the token.

31. The method of claim **30**, wherein the associated arc segment subtends an angle of about 160 degrees from a center of the token.

32. The method of claim **29**, further comprising correlating patterns within the region of the linear layer with patterns within each of the sub-group of the plurality of template match candidates to calculate a pattern correlation value, wherein the pattern correlation value indicates a degree of similarity between the region of the linear layer and the associated template match candidate of the sub-group.

33. The method of claim 32, wherein correlating patterns within the region of the linear layer with patterns within each of the sub-group of the plurality of template match candidates further comprises comparing the patterns within the region of the linear layer with the patterns within each of the sub-group of the plurality of template match candidates using a normalized squared difference function, and the normalized square different function returns the pattern correlation value.

34. The method of claim 33, further comprising associating, with the processor, the pattern correlation value returned for each of the sub-group of the plurality of template match candidates with the associated template match candidate of the sub-group.

35. The method of claim 32, further comprising:

matching the region of the linear layer with an associated region of each of the sub-group of the plurality of template match candidates, wherein the region of the linear layer and the associated region of each of the sub-group of the plurality of template match candidates having substantially the same image size;

thresholding the associated region of each of the sub-group of the plurality of template match candidates; and

comparing pixels of the region of the linear layer with pixels of the thresholded associated region of each of the sub-group of the plurality of template match candidates to determine a pixel correlation value, wherein the pixel correlation value indicates a number of pixels in the region of the linear layer not present in the thresholded associated region of each of the sub-group of the plurality of template match candidates.

36. The method of claim 35, further comprising combining, with the processor, the pattern correlation value and the pixel correlation value to calculate a final correlation score for each of the sub-group of the plurality of template match candidates.

37. The method of claim 36, further comprising determining, with the processor, whether the final correlation score for each of the sub-group of the plurality of template match candidates exceeds a threshold score, wherein a final correlation score exceeding the threshold score indicates a match between the region of the linear layer and an associated template match candidate.

38. The method of claim 37, wherein a final correlation score below the threshold score indicates the presence of a token associated with the linear layer.

39. The method of claim 38, wherein identifying an optimal template match candidate of the plurality of template match candidates comprises identifying, with the processor, an optimal final correlation score from the final correlation scores for each of the sub-group of the plurality of template match candidates.

40. A method of operating a gaming table having at least one bet placement surface thereon for supporting a stack of gaming tokens at a location, the method comprising:

capturing, with an image sensor, an image of a lateral side surface of at least one gaming token at the location, wherein the lateral side surface is depicted in a radial format;

converting the image, with a processor, into a converted image depicting the lateral side surface of the at least one gaming token in a form of a linear layer, the converting comprising:

removing background elements from the image prior to converting the image to form a background-subtracted image; and

identifying, in the background-subtracted image, boundaries of the at least one gaming token;

thresholding the background-subtracted image to produce a thresholded image having zero points and non-zero points;

identifying, with the processor, at least three radially outermost non-zero points in the thresholded image;

outlining a circle extending through the at least three radially outermost non-zero points with the processor;

associating the circle with an outline of the lateral side surface of the at least one gaming token;

acquiring image data from the linear layer of the converted image with the processor; and

analyzing the image data to determine a wager value of the at least one token.

41. The method of claim 40, further comprising:

calculating a radius of the circle; and

correlating, with the processor, the radius of the circle with known token data stored in memory associated with the processor to estimate a total number of gaming tokens present in the stack of gaming tokens; and

wherein identifying, in the background-subtracted image, boundaries of the at least one gaming token comprises correlating the estimated total number of gaming tokens present in the stack of gaming tokens with data in the background-subtracted image to identify the boundaries of the at least one gaming token.

42. The method of claim 41, wherein the edge detection algorithm comprises a difference of Gaussians algorithm.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,478,099 B2
APPLICATION NO. : 14/500687
DATED : October 25, 2016
INVENTOR(S) : Zbigniew Czyzewski et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Specification

Column 7,	Line 53,	change "inclination a of" to --inclination α of--
Column 10,	Line 23,	change "plane foamed by" to --plane formed by--
Column 15,	Line 21,	change "to perforin at" to --to perform at--
Column 20,	Line 50,	change "RGB for rat image" to --RGB format image--
Column 23,	Line 50,	change "outeinost points" to --outermost points--
Column 32,	Lines 41-42,	change "Theremovable attachment" to --The removable attachment--

In the Claims

Claim 20, Column 38, Line 57, change "portion each" to --portion of each--

Signed and Sealed this
Tenth Day of January, 2017

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office